Instruments

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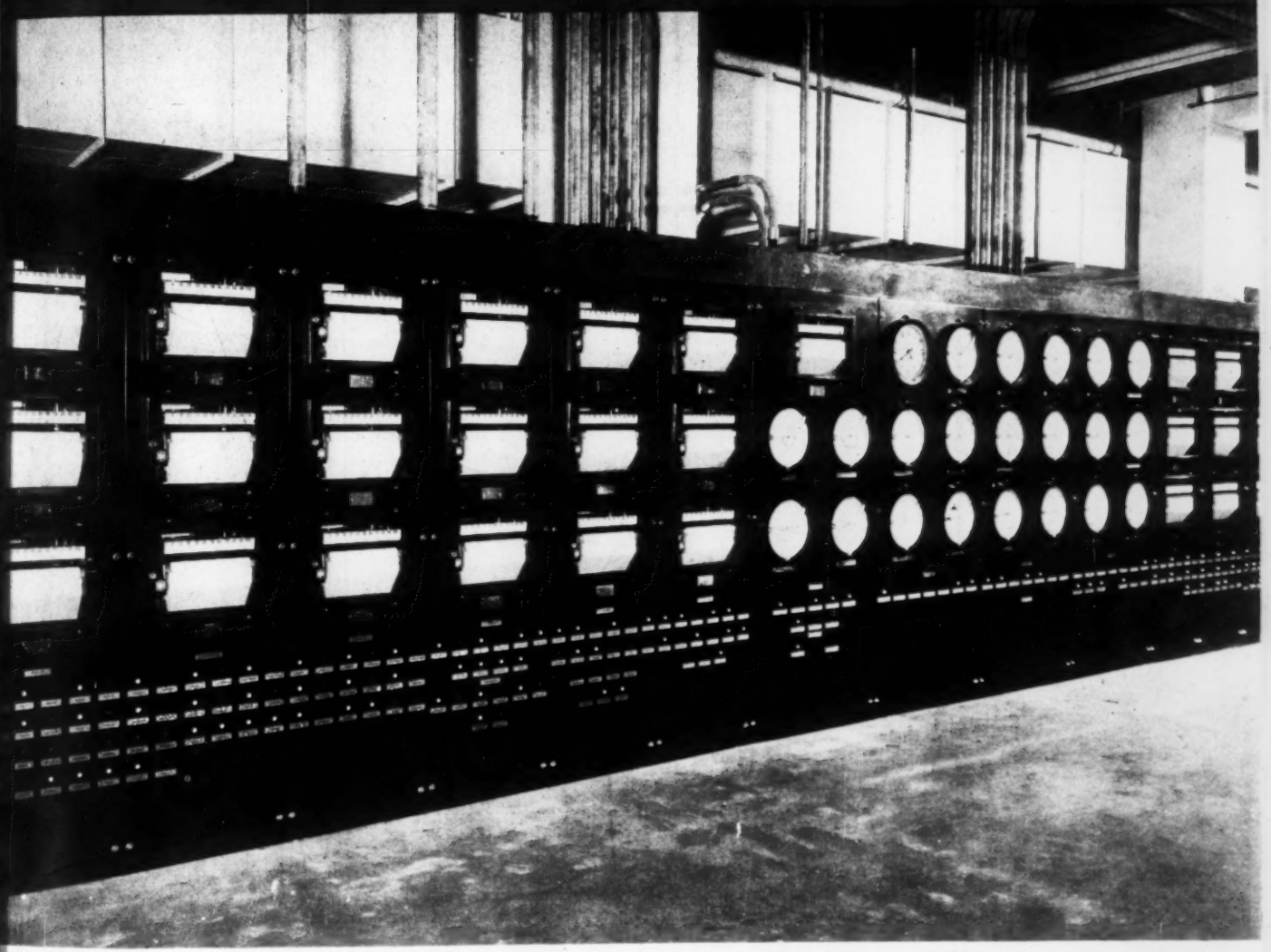

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HEATING, VENTILATING & AIR-CONDITIONING CONTROL BOARD IN SOCIAL SECURITY & RAILROAD RETIREMENT BLDG., WASHINGTON

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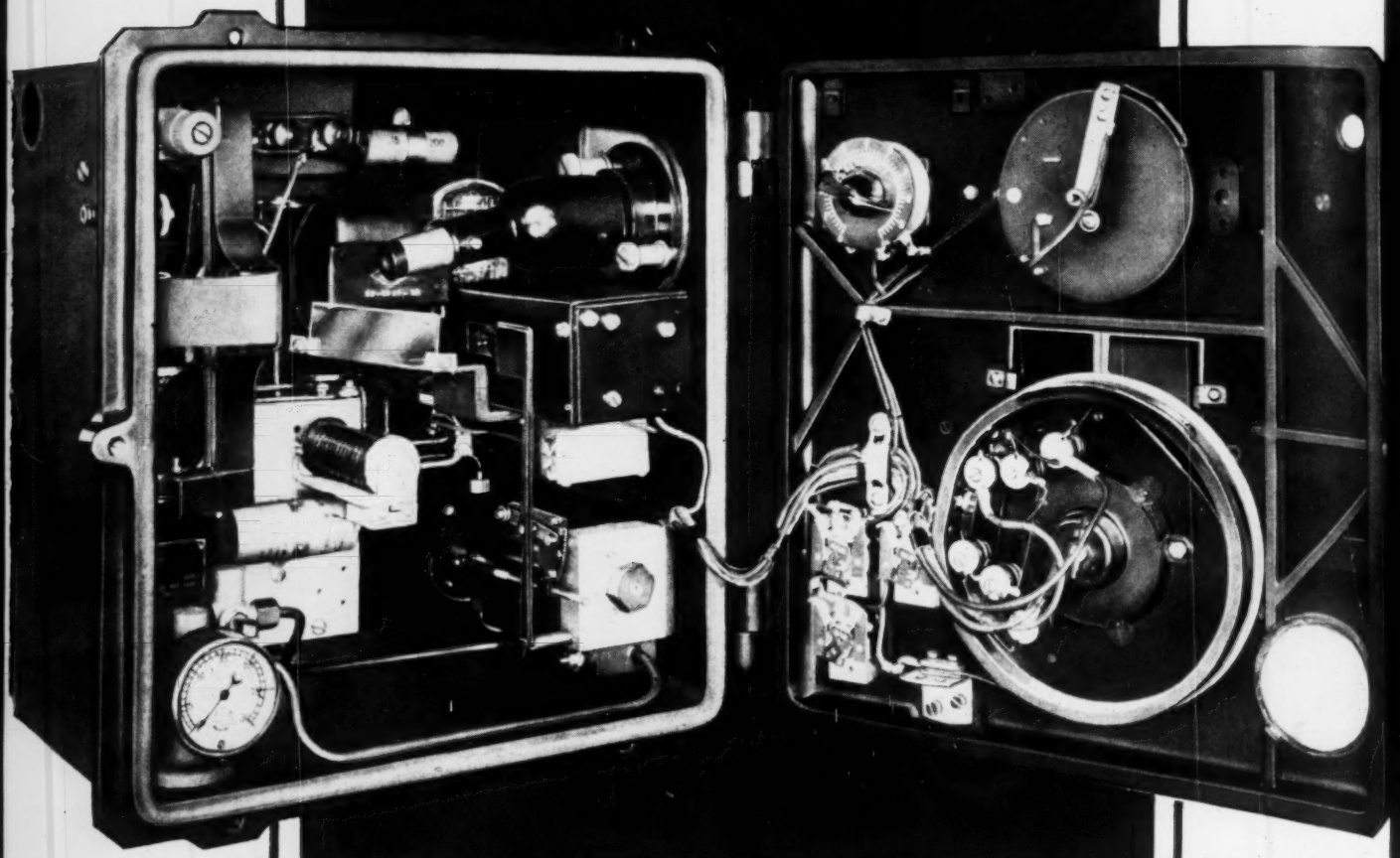

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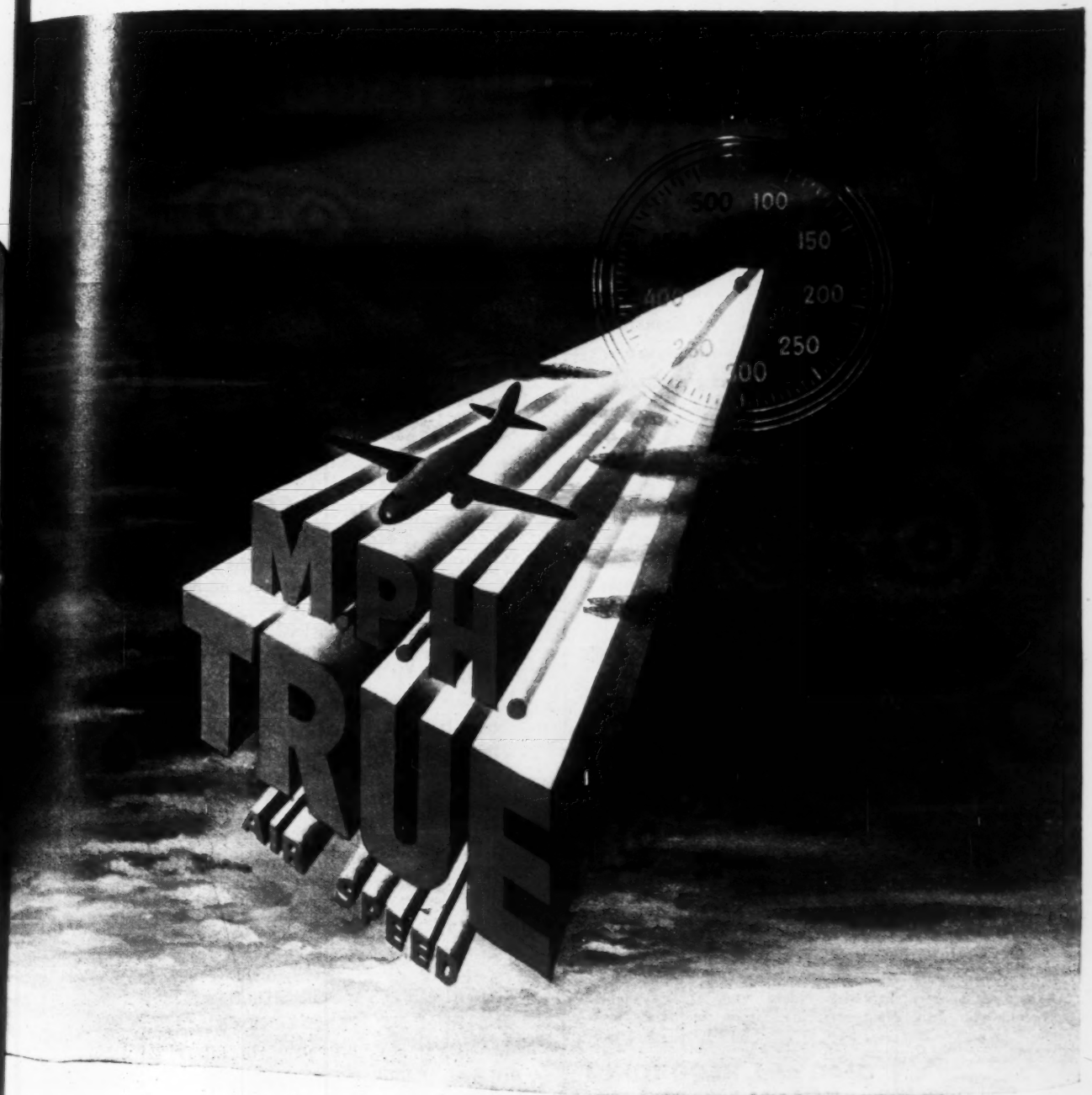

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Vol. 17 OCTOBER 1944 No. 10

COVER: Air-conditioning control board, Social Security & R. R. Retirement Bldg., Wash., D. C. *(Photo courtesy Nat'l Fuel Conservation Program)*

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EDITORIAL COMMENT

"Fuel Saving Starts With Control"

IT is a pleasure to coöperate with a Government-Industry team which advocates the use of instruments as essential weapons in the War on Waste. This team is known as the National Fuel Efficiency Program, Bureau of Mines, Department of Interior. They asked us for our front-cover picture space and we're gladly giving it to them. There is also a National Fuel Efficiency Council headed by Thomas Cheasley, Fuel Engineer of Sinclair Coal Co., Kansas City, who serves also as Supervising Engineer of the Bureau of Mines' Fuel Efficiency Section. A few weeks ago nearly a thousand men (most of them combustion engineers, some of them old *Instruments* subscribers) were appointed as Area Coördinators, Regional Engineers and "Waste Chasers" and Interior Secretary Harold L. Ickes declared that—

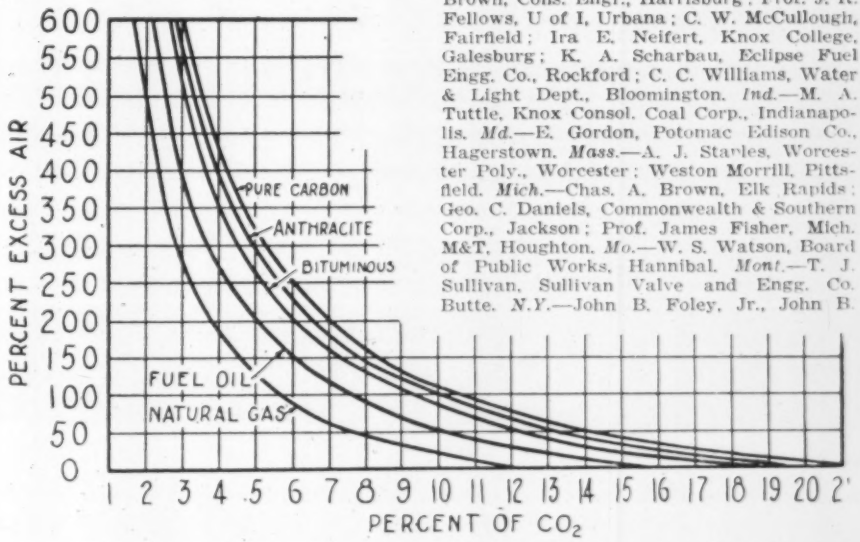
"The counsel given free of charge by the volunteer engineers will not encroach upon the activities of commercial firms which provide technical advice and the services of consulting engineers in redesigning or making replacements in plants."

A list of the Area Coördinators is appended. Look up the nearest one and start SAVING MORE FUEL through Instrumentation—if you haven't yet done so.

The October 1938 issue of *Instruments* was a special one devoted to automatic combustion control. Look it up in your company library or the nearest technical library.

Of special interest to our readers is the "Fuel Conservation Council for War, Automatic Controls Industry," P. O. Box 1175, Milwaukee, Wis., which has issued a 32-page manual entitled "Conserving Fuel with Automatic Controls and Instruments" written in non-technical language for managers of hotels, institutions, office buildings, etc., as well as for industrial plant engineers.

Of more specific interest are the technical books and pamphlets written for engineers, which for many years have been issued by manufacturers of automatic combustion control equipment. Without implying that one engineer's or one company's educational work is the best, I might mention that as a "refresher" for preparing this editorial I studied at home my binder of Hays Corp. technical monographs written by W. H. Pugsley, and decided that a chart* which appears in several of these bulletins would be of special value to *Instruments* readers who want to help save fuel, because I haven't seen anything like it in the NFEP or FCCW literature. Here it is, in 4½" width so you can read it easily:—



As to the other important factor, keeping down flue-gas temperature, most of the so-called "efficiency charts" being mailed out during this campaign seem to me to give false hopes† so I've made up this little table:—

%CO_2	% Coal LOST as heat carried up the flue when Flue gas Temp. is 800°	700°	600°	500°	400°	300°
8	26.7	23.2	19.5	15.9	12.3	8.6
10	22.4	19.4	16.4	13.3	10.3	7.2
12	19.2	16.6	14.0	11.3	8.8	6.1
14	16.9	14.6	12.3	10.0	7.7	5.4
16	15.0	12.9	10.9	8.9	6.8	4.8
18	13.2	11.4	9.6	7.8	6.0	4.2

Note—Based on local values and on assumption that "other things remain equal," the above loss figures are conservative, may be higher in actual cases.—MFB

*Mr. Pugsley states that his chart was made from data in "Heat Loss Analysis" by E. A. Uehling (McGraw Hill Book Co.).

†For example, "52% efficiency" implying a 48% *preventable* waste!

But there are numerous things to do, other than maximizing CO_2 and minimizing flue gas temperature, so get in touch with your NFEP Area Coördinator, whose office will have the nearest "Waste Chaser" help you solve your own particular problem.—M. F. BEHAR

AREA COORDINATORS AND HEADQUARTERS:

Calif—J. J. Wilt, Bakersfield; J. B. Hawley, Luppen & Hawley, Sacramento; R. J. Phillips, San Diego Gas & El. Co., San Diego. *Conn.*—Allen Hubbard, Cons. Engr., New Haven. *Fla.*—A. P. Michaels, Cons. Engr., Orlando. *Ga.*—H. R. Creamer, Augusta Ice & Coal Co., Augusta; Prof. Josiah Crudup, Mercer U., Macon. *Ill.*—Ralph D. Brown, Cons. Engr., Harrisburg; Prof. J. R. Fellows, U of I, Urbana; C. W. McCullough, Fairfield; Ira E. Neifert, Knox College, Galesburg; K. A. Scharbau, Eclipse Fuel Engg. Co., Rockford; C. C. Williams, Water & Light Dept., Bloomington. *Ind.*—M. A. Tuttle, Knox Consol. Coal Corp., Indianapolis. *Md.*—E. Gordon, Potomac Edison Co., Hagerstown. *Mass.*—A. J. Starles, Worcester Poly., Worcester; Weston Morrill, Pittsfield. *Mich.*—Chas. A. Brown, Elk Rapids; Geo. C. Daniels, Commonwealth & Southern Corp., Jackson; Prof. James Fisher, Mich. M&T, Houghton. *Mo.*—W. S. Watson, Board of Public Works, Hannibal. *Mont.*—T. J. Sullivan, Sullivan Valve and Engg. Co. Butte. *N.Y.*—John B. Foley, Jr., John B. Foley, Jr. Co., Syracuse. *N.C.*—Frank E. P. Klages, Powers Regulator Co., Greensboro. G. A. Morris, Norfolk & Western Railway Co., Winston-Salem. *N.D.*—J. F. McGuire, Northern States Power Co., Fargo. *O.*—L. F. Wertz, Office of Trustee of Public Affairs, Lebanon. *Okla.*—W. Schumacher, Public Service Co. of Oklahoma, SW Div., Lawton. *Ore.*—Albert Thews, Thews & Ryder, Pendleton. *Pa.*—E. A. Reilly, Phila. & Reading Coal & Iron Co., Pottsville; C. Schillinger, Coxe Stoker Engg. Co., Hazelton; A. S. Wertz, Wertz Engg. Co., Inc., Reading; H. A. Delano, Am. Chain Div., York. *S.D.*—R. M. Crooks, Sioux Falls Gas Div., Sioux Falls. *Tenn.*—L. C. Peal, Supt. Smoke Regul., City of Nashville, Nashville. *Tex.*—Lloyd D. Royer, Cons. Mech. Engr., San Antonio; Clem R. Winkler, United Gas Corp., Beaumont; Wm. H. Rouzer, Jr., Petroleum Engr., Wichita Falls. *Vt.*—F. W. Kehoe, Univ. of Vermont, Burlington. *W.Va.*—E. J. Kerr, Island Creek Coal Sales Co., Huntington; F. C. Sweeney, Weirton Steel Co., Weirton. *Wis.*—F. W. Johnson, Rhinelander Paper Co., Rhinelander.

Happy Birthday, William Gaertner!

IF, on October 24, 1864, a suitable timing instrument had been set at "0," it would register "80 years" on the 24th of this month. In this purely chronometric sense, the four-score mark will be reached by William Gaertner, founder and President of the Gaertner Scientific Co., Chicago.

In the biological sense, however, William Gaertner is not an octogenarian. The last time I saw him—just a few days ago—I was thinking that most men of sixty would envy him his physical condition . . . and most men of all ages his mental alertness: some question came up about an important delivery date, and his grasp of all factors proved that he was master of the situation—a few jumps ahead of whoever raised any point—like a master of chess playing several amateurs simultaneously. Not once did his benign smile vanish; not once was his voice other than gentle.

Let other technical journals recite the details of William Gaertner's career as designer and builder of high-precision instruments with Appel in Göttingen, with Repsold in Hamburg, with Hilger in London, with Caminda in Rotterdam, with Kraft in Vienna, with Buff & Berger in New York, with the U.S. Coast & Geodetic Survey, with the Smithsonian Institution in Washington and with the Kenwood Observatory in Chicago before he founded his firm in 1896! Let them list the noteworthy telescopes, astrophotometers, spectrographs, interferometers, dividing machines, heliostats and chronographs his company built for famous observatories and laboratories! Let them print then-and-now pictures of his plant! . . . What it behooves me to chronicle on this occasion is that William Gaertner, who became a citizen of the United States forty-eight years ago, possesses all the qualities that are implied in the words "A Loyal and Useful and *Great* American Citizen." —M. F. BEHAR

A Portable All-purpose A-c. Instrument Test Set

By J. SPENCER, Foreman, Meter Division, Westinghouse Elec. & Mfg. Co., Newark, N. J.

IDLE or defective equipment has no place in American industry especially during war-time. Breakdowns usually can be avoided if normal precautions are exercised in maintaining and servicing the monitoring measuring devices. Erroneous instrument indications often result in lowering the quality of the manufactured product. Such trouble may cause breakdown of equipment (overloading mechanically or electrically) and may, in time, ruin the instrument itself.

Precautions to prevent such difficulties have been cited many times—nevertheless, they go unheeded. Oftentimes, they are not observed for want of qualified personnel and of proper auxiliary equipment (electrical standards and circuits with suitable controls). Instrument schools are now established in almost every large industrial community and instrument manufacturers are generous in supplying information on the subject of maintenance. Recently, the writer completed a book* that covers the subject in detail.

Cost of adequate equipment to properly protect instruments is not excessively high—as a matter of fact, it is quite reasonable. For example, let us consider the a-c. all-purpose portable test set built by the writer and shown in Fig. 1. With this type of equipment a service man has the equivalent of a modern laboratory test bench, with electrical standards and controls for the various circuits.

*J. Spencer. Maintenance and Servicing of Electrical Instruments. Instruments Publishing Co., Pittsburgh, 1944.

Power necessary for this equipment comes from a 110-volt 60-cycle circuit. With this input, the set is complete with controls and standards for testing and calibrating a-c. ammeters, milliammeters, voltmeters, wattmeters, power factor meters and synchroscopes. The set also has a phase sequence indicator, continuity test circuit and a "pencil soldering" outfit. It weighs approximately 35 lbs. and was constructed by the writer to fill the needs of instrument service and maintenance men, whose duties often call them to places where testing facilities are not available. Trade schools, small power plants and repair shops should also find such equipment of considerable value.

This test outfit is not available on the market. Information given, however, should be of value to instrument service men who desire to assemble such a set for their own use. It consists entirely of readily-obtainable standard parts as follows:

1. One wood carrying case 6"×12"×6½".
2. One small type (2½-amp.) "Variac."
3. One small limiting resistor.
4. One triple-deck double-contact Yaxley switch.
5. One triple-deck single-contact Yaxley switch.
6. Two small transformers (radio type).
7. Two midget neon bulbs.
8. One 0.1-microfarad capacitor.
9. One set of small spool resistors for power factor circuit.
10. Ammeter.
11. Voltmeter.
12. Wattmeter.

Parts are mounted on an insulating panel and are connected electrically as in Fig. 2.

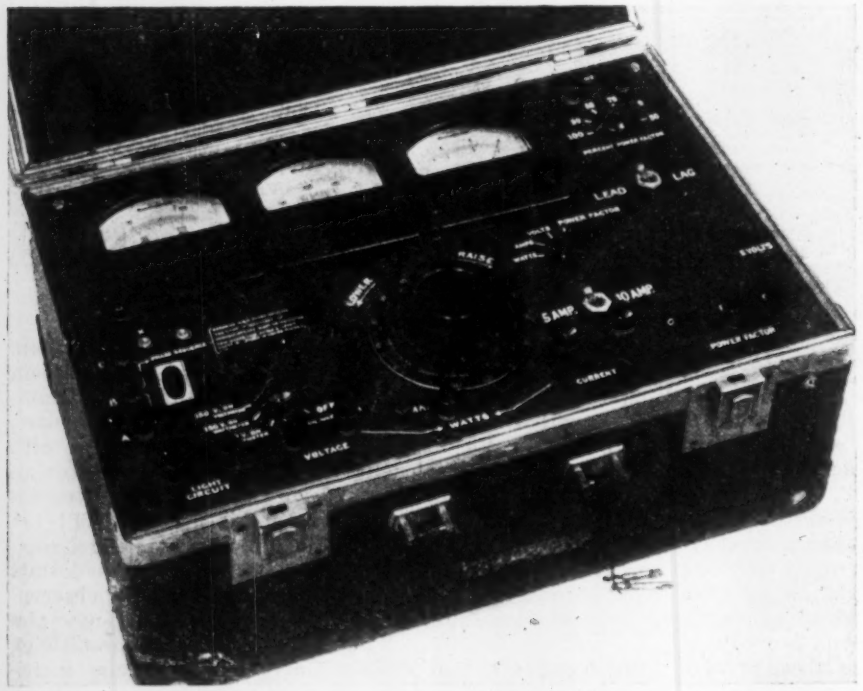


Fig. 1. The all-purpose portable test set, for testing and calibrating a-c. ammeters, milliammeters, voltmeters, wattmeters, power factor meters and synchroscopes.

INSTRUCTIONS FOR USE

Fig. 1 shows that switching arrangements and terminal connections (for the various kinds of measurements) are clearly marked. Input terminals are on the upper right hand corner of the panel and are marked LINE.

Voltmeter tests are made with selector switch B set at the point marked VOLTS and with switch D set to the voltage range desired. Instruments to be tested are connected to terminals marked VOLTAGE and the Variac is used to control and vary the potential.

Ammeters.—To test or calibrate ammeters, the instrument to be tested should be connected to the terminals of the set marked CURRENT. Selector switch B should be set at the point marked AMPS and switch D setting be at the 150-volt voltmeter point. For lower current readings, set the limit resistor knob on or below the 5-ampere point and adjust the Variac control knob for varying the supply. For high current readings, adjust the limit resistor to approximate the desired current and make final adjustment with the Variac.

Milliammeters are tested by connecting the terminals of the instrument to the set terminals marked MILLIAMPS. Selector switch B should be set on the voltage point and the setting of selector switch D should be on the point marked M.A. The voltmeter is calibrated in milliamperes as well as volts and hence serves as the milliampere standard with settings and connections as outlined. Here again the Variac is the controlling mechanism.

Wattmeters.—Connect the series circuit of the wattmeter to the terminals marked CURRENT and the wattmeter potential circuit to the terminal marked VOLTAGE. Set selector switch B on point marked WATTS and selector switch D on the 150-volt or 300-volt point marked ON WATTMETER. The point selected will be determined by the potential rating of the instrument under test. A toggle switch marked 5-AMP. and 10-AMP. is provided to take care of test instruments of different current coil ratings. With these settings and connections, the set is ready for wattmeter testing, the Variac being used to increase or decrease the current and hence vary the wattmeter reading.

Power Factor Meters are tested by connecting the series circuit of the instrument to the terminals of the set marked current and the potential terminals of the instrument to the corresponding A,B,C terminals marked POWER FACTOR. Selector switch B should be set on the point marked POWER FACTOR and the toggle switch marked 5 AMPS and 10 AMPS should be set to the side corresponding nearest to the current

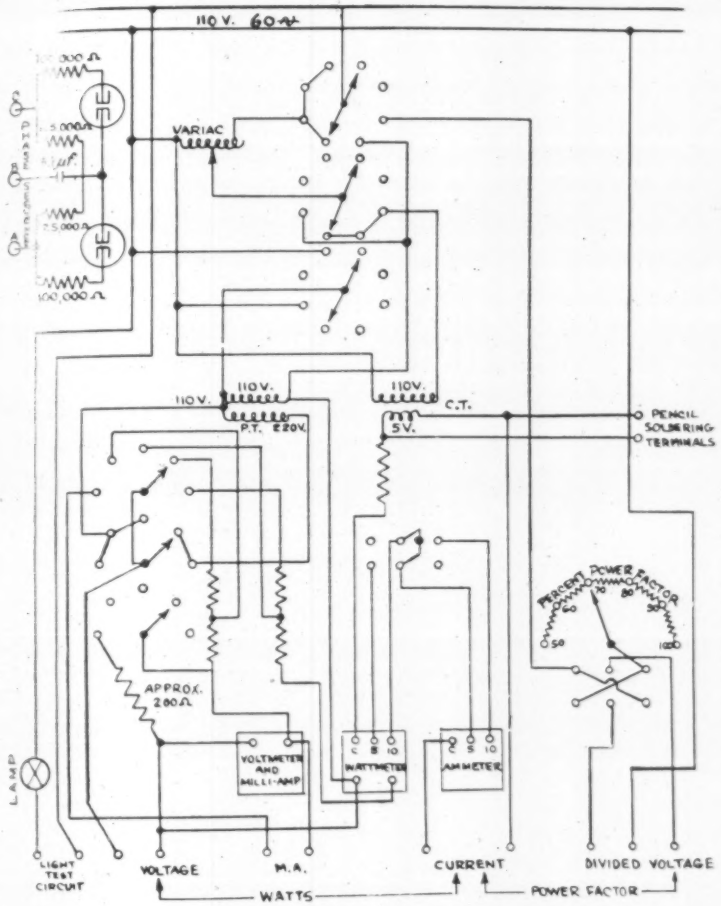


Fig. 2. Wiring diagram of the portable test set.

rating of the instrument. The current applied to the instrument may be controlled by manipulating the Variac knob and the current input to the power factor meter will be indicated on the ammeter of the test set. Power factor indications are varied by setting selector switch A on the point (percent power factor) desired and flipping the toggle switch marked LAG and LEAD to the side required.

Synchroscopes can be tested by using the milliampere arrangement of the set when adjusting or equalizing the two branches of the split-phase circuit of the test instrument. The synchroscope can then be set for bucking, that is the 12 o'clock position, by connecting the incoming machine and the running machine terminals of the synchroscope to the terminals of the set marked VOLTAGE and normal voltage applied.

Phase Sequence of a polyphase circuit may be checked by connecting the circuit leads to terminals on the set marked PHASE SEQUENCE. Assuming A,B,C phase rotation, the lamp marked X will light if connections are made as indicated. This means that phase A leads phase B, phase B leads phase C, etc. If the leads are not connected as indicated, the other lamp will light and leads should be interchanged until lamp X lights.

Continuity checks can be made by connecting test leads to set terminals marked LIGHT CIRCUIT. Closed circuits will be indicated by a light from the lamp seen through aperture near the phasing lamps.

Since pencil soldering has been found so useful in instrument work, provisions are made in the set for this purpose. The leads for pencil soldering may be connected to the marked terminals at the right side of the panel.

A Supply and Control Unit for Electrical Instrument Testing and Calibration

By J. SPENCER, Foreman, Meter Division, Westinghouse Elec. & Mfg. Co., Newark, N. J.

IN a previous article the writer described an all-purpose a-c. portable test set. This outfit includes a power supply unit with controls and a set of electrical indicating instrument standards. Since, however, most instrument service men have portable instruments available as standards, their problem is to have at hand a controllable electrical source of supply.

The simple power supply unit here described meets this requirement. It will serve to test practically all kinds of a-c. instruments.

This unit can also be used as an auxiliary to an industrial analyzer as shown in Fig. 1. The added value of the analyzer would be as a calibrating test set for ammeters, voltmeters, wattmeters, power factor meters, and as an indicator for checking phase sequence. Fig. 1 shows a typical test set-up for checking a wattmeter, using an industrial analyzer as the checking standard.

Note in Fig. 1 that the instrument under test has a megawatt scale. Its actual capacity is 500 watts: 5-ampere series circuit and 150-volt potential circuit. Its calibration in megawatts is determined by the ratios of the transformers with which it is to be used. It is recommended that a standard wattmeter having 5-10-amp. and 150-300-volt circuits be used with this test set as these ratings cover more than 95% of all switchboard wattmeters in use.

The arrangement of circuits and controls is shown in Fig. 2. Fig. 3 is a general view of the unit.

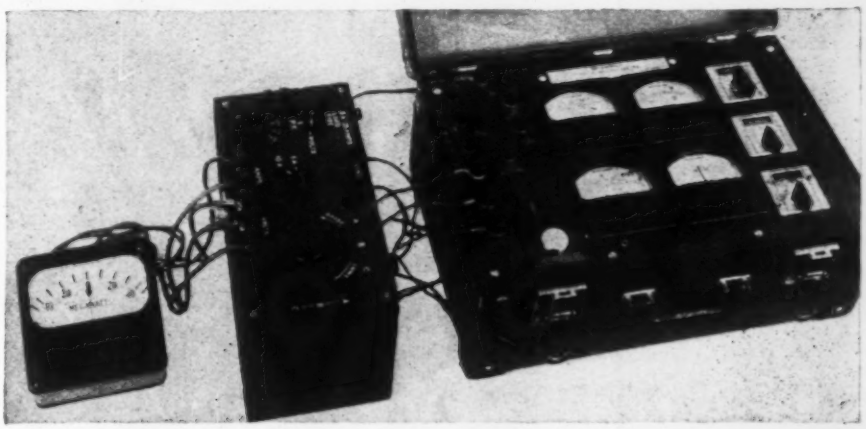


Fig. 1. Power supply unit used in conjunction with a Westinghouse Type TA Industrial Analyzer.

This outfit is not a manufactured product. With the information given, any qualified service man could assemble a unit of this kind.

The parts required for this set are as follows:

One wooden carrying case
One small type (2½-amp.) "Variac"
One small limiting resistor
One triple-deck double-contact Yaxley switch
One triple-deck single-contact Yaxley switch
Two small transformers (110/220-v. 75-va.) (110/5-v. 100-va.)
Two midget neon bulbs
One 0.1-microfarad capacitor
One set of resistors (see phase sequence diagrams Fig. 3)

These parts (other than the wood case) are mounted on an insulating panel and are connected electrically as shown in Fig. 2.

From a study of the circuit diagram, Fig. 2, it will be seen that by a simple switching arrangement, the same controls and supply are used for the many different kinds of a-c. instrument tests. The photograph, Fig. 3, shows the terminal connections, switches and controls clearly marked to simplify the use of the unit. The input terminals marked LINE are conveniently located in the center of the set. As a further means of understanding the workings and connections of the test unit, a few of the uses are outlined.

For *ammeter* testing, switch A should be set on position marked AMPS. This connects the primary of the Variac across the supply line and the secondary across the primary of the current transformer. With this setting, the output at the terminals marked CURRENT may be controlled by the use of the Variac in the set.

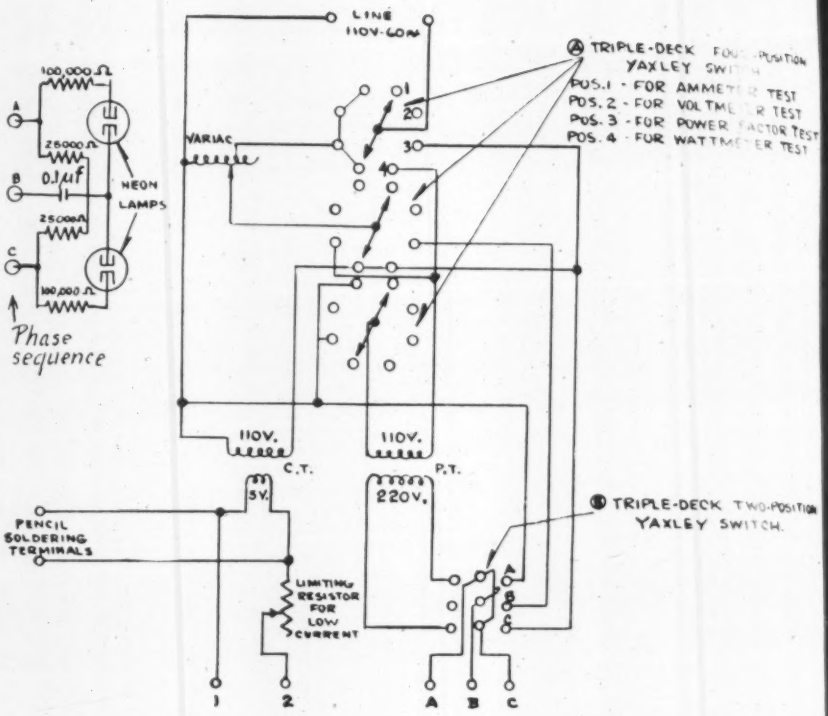


Fig. 2. Wiring diagram showing connections of various elements of the power supply unit.

Voltmeters may be tested by connecting to the set terminals marked A and C. For this purpose, switches A and B should be set at the points marked VOLTS. This places the control Variac primary across the line and the secondary across the primary of the potential transformer of the set.

Wattmeter current terminals should be connected to the current terminals of the set and wattmeter potential terminals connected to terminals A and C of the set. Switch A is set at the point marked WATTS and switch B at the setting marked VOLTS. With these connections and settings, the Variac is used to vary the current output of the set and hence change the wattmeter indications. The same connections are used for polyphase wattmeter test using the single-phase test method as outlined in a recent book* by the writer.

Power factor meter test connections are instrument current terminals to set current terminals and potential terminals A,B,C of the instrument to the set terminals A,B,C. The switch settings should be the P.F. point on both A and B switches. With these connections and settings, the current output of the set is held constant and the Variac is used to divide the voltage between A B and B C.

When the Power Supply Unit is used as an auxiliary to the Industrial Analyzer the connections are as follows: Terminals A,B,C of the set are connected to line terminals A,B,C of the analyzer, current terminal No. 1 of the set is connected to line terminal A of the analyzer and current terminal No. 2 of the set is connected to load terminal A of the analyzer.

For *Phase sequence* checks, the same procedure as outlined in my previous article on the a-c. all-purpose test set should be followed, as the indicators in both sets are identical.

This device also includes a circuit and connections for a "Pencil Soldering Set," an extremely useful tool.

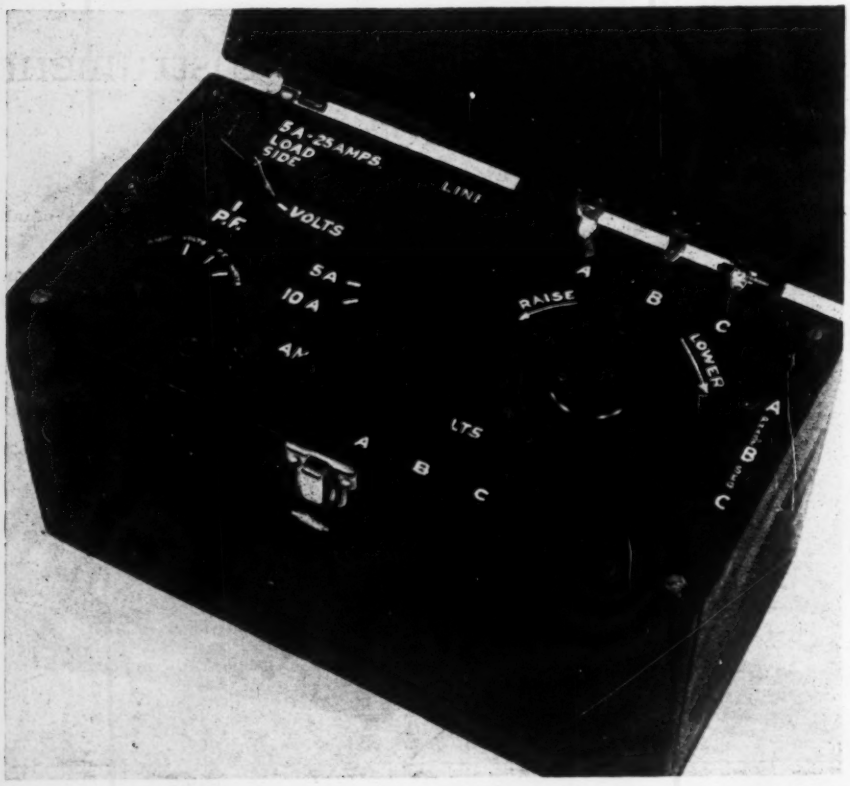


Fig. 3. Portable unit which provides a controllable source of a-c. power.

*J. Spencer. Maintenance and Servicing of Electrical Instruments. Instrument Publishing Co., Pittsburgh, 1944.

The SIGNIFICANCE of ACCURACY of Electrical Indicating Instruments

By M. S. WILSON, Designing Engineer, Instrument Engineering Div., West Lynn (Mass.) Works, General Electric Co.

ELECTRICAL instruments are among the most important peacetime devices now used in fighting equipment. Mechanized warfare would hardly be possible without them. Their failure may mean the loss of life or the destruction of vital fighting equipment. They must, therefore, be accurate and reliable.

For the best results it is necessary to obtain instruments suitable for the application, and they must be correctly applied. A brief review of instrument accuracy under different conditions and a discussion of the more important factors which affect instrument performance may be timely and useful.

EDITOR'S NOTE — "Confession is good for the soul." I confess that when I received this article my impulse was to reject it in view of the rigid WPB paper-limitation orders and the number of previously-accepted articles. The original manuscript consisted of 25 typewritten pages and eight illustrations (at first glance "commercials"). It seemed to contain no topic not yet discussed thoroughly in *Instruments*. Its title was uninviting. Its emphasis on the old C39.1 without even a mention of War Standard C39.2* seemed biased. Oh, I thought I had lots of reasons for not giving precious *Instruments* space to "old stuff." But when I read it line-by-line critically, I discovered its value—and so will you! In spite of its title it is a PRACTICAL discussion of accuracy. It explains ALL important factors: just glance at this list—→ Its author understands the USER's problems. Finally, it goes beautifully with the foregoing articles by Spencer on calibration set-ups. —M. F. Béhar

*See *Instruments*, April 1943.

INITIAL ACCURACY

It has been the custom for a number of years to state the accuracy of most electrical measuring instruments in percent of the full-scale value. For example, a one-ampere instrument having the zero point at the end of the scale, which is rated as 2% accuracy, would have an allowable error of 0.02 ampere at any point on the scale. In the case of instruments with the zero point in the center of the scale the accuracy is expressed as a percentage of the sum of the full-scale readings to the right and left of the zero point. For example, an instrument rated 0.5 - 0 - 0.5 ampere and 2% accuracy has an allowable error of 0.02 ampere at any point on the scale.

The reason for stating the accuracy as a percentage of full-scale value is that errors resulting from friction of the bearings, inaccuracies in reading the scale, and those due to incorrect positioning of the graduation lines on the scale, etc., are independent of the scale reading. Since errors of this type may be of the same magnitude for any scale point they would, if the accuracy were stated as a percentage of the point read, become an increasingly greater percentage as the scale reading decreases. An instrument, therefore, which has a friction error of 0.1% of full-scale value would have an error of 1% of the point at 10% of the scale, and 10% of the point at 1% of the scale reading. If this system were used it would be necessary to have a different accuracy rating for different scale points. This would be impractical.

The following are exceptions to the rule of stating the accuracy as a percentage of the full-scale value as covered by American Standards for Electrical Indicating Instruments C39.1, issued by the American Standards Association:

1. The accuracy of a frequency meter shall be expressed as a percentage of the indicated frequency.
2. The accuracy of a power-factor meter shall be expressed as a pure number (preferably a decimal fraction).
3. The accuracy of a phase-angle meter shall be expressed in electrical degrees.
4. The accuracy of an ohmmeter shall be expressed as a percentage of the scale length.

The accuracy of instruments varies with the class and size. The accuracy of indicating instruments as covered by ASA Specification C39.1 is given below:

The initial accuracy of alternating and direct current instruments through the measurement range* at the reference temperature of twenty-five degrees Centigrade and with the instrument in its normal position shall be as follows:

	Limits of Initial Accuracy
Switchboard instruments having a scale length less than 4½"	2%
Switchboard instruments having a scale length greater than 4½" Ammeters, voltmeters and wattmeters	1%
Power-factor Meters, 1/5 rated current and above	0.01 p.f.
Frequency Meters, 60 Cycles	0.5%
Frequency Meters, 25 Cycles	1%

Portable Instruments	*Grade A*	*Grade B*
Voltmeters	0.3%	0.8%
Ammeters and Milliammeters	0.5%	0.8%
Wattmeters (single-phase)	0.3%	0.8%
Wattmeters (polyphase)	0.5%	—

A Grade A Portable Instrument is defined as a portable instrument intended for uses which warrant the best available commercial instrument as to accuracy under normal conditions and as to low values of the various applicable influences.

A Grade B Portable Instrument is defined in general as a portable instrument intended for uses for which moderate accuracy and moderate values of the various applicable influences are sufficient.

Additional Accuracy Tolerances, Switchboard Instruments Used with Instrument Transformers. When a switchboard instrument is used in connection with one or more current transformers or with one or more voltage transformers, an additional accuracy tolerance of 1% shall be added to the limit of accuracy for the instrument proper. When a switchboard instrument is used with both kinds of transformers, the additional accuracy tolerance shall be 1.5%.

*The measurement range is not covered by ASA Specifications. It is usually taken as the complete scale range for instruments having uniformly graduated scales and the upper 4/5 of the linear length of the scale for instruments having non-uniform scales.

CAUSES OF ERRORS IN INSTRUMENTS

It is important that the user realize that the "initial" accuracy of an instrument may not obtain under some conditions of use and that precautions are necessary to insure the highest accuracy. The more important factors that affect the accuracy of indicating instruments are as follows:

1. Readability
2. Position Error
3. Effect of Electromagnetic Fields
4. Effect of Ambient Temperature Changes
5. Electrostatic Effects
6. Effect of Self-heat
7. Effect of Changes in Frequency for A-c. Instruments
8. Effect of Changes in Voltage on Accuracy of Wattmeters, Frequency Meters and Power-factor Indicators
9. Effect of Wave-form on Accuracy of A-c. Instruments

1. Readability

The readability of an instrument is determined principally by scale length, layout of scale, type of pointer, distance of pointer from scale, and whether or not the instrument is provided with an anti-parallax feature such as offset scale or mirror scale. (The parallax error is that which is caused by moving the eye in relation to the pointer.)

The scale length should be such that the reading error does not use up a large part of the accuracy tolerance. For example, in a given small-size panel instrument, the scale length is 1.6". The maximum reading error as found by ten observers was ¾%. With an accuracy rating of 2% (which is normal for such an instrument) this permits ⅜ of the accuracy limit to be used up in reading the instrument and the remaining accuracy limit for all other errors. To rate such an instrument as "1% accuracy," for example, would require that all other errors be eliminated, which is impracticable in this class of instrument.

As another example, a portable instrument intended for precision measurements, such as the General Electric Type DP-2, is rated as 0.2% initial accuracy. The maximum reading error for ten observers in this type of instrument was 0.07%, a little more than ⅓ of the total allowable error. For this type of instrument the other errors under normal conditions will not exceed the remaining 0.13%. In an instrument of this accuracy classification it is desirable to provide means by which the instrument may be read to at least 0.1% accuracy. In the Type DP-2 instrument these consist of a scale 5" in length, a knife-edge pointer and mirror scale to eliminate the parallax error. By lining up the pointer so that it hides its image in the mirror the eye is exactly over the pointer and consistent readings can be obtained.

Still another example is the 4¼" instrument (switchboard type) rated 1% initial accuracy. In this new design of a "concentric scale" instrument which General Electric placed on the market four years ago, the scale length is in general 6¾". To accomplish this a pointer deflection of 240° is used as compared to the normal 90° to 100° scale. This means that the readability has been increased in the order of two and one-half times. The long scale length, together with the offset scale as shown in Fig. 1, permits reading the instrument at a considerable distance with negligible readability error.

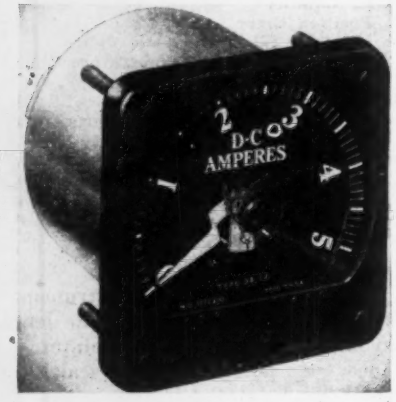


Fig. 1. G.E. Concentric-scale Type DB-12 switchboard instrument, 4¼" size.

2. Position Error

In general this error is caused by the "out-of-balance" of the armature. To prevent it, the mechanical balance of the armature must be so adjusted that the pointer will maintain the same reading within reasonable limits even though the instrument is tilted at an angle from the normal operating position. This error is minimized by using balance weights on the moving system which are accurately adjusted by the manufacturer and stay put in use. It also is necessary that the armature be stabilized so that temperature and humidity changes met with in service will not upset the original balance. This requires careful selection of materials, correct alignment of parts, and careful heat treatment in order to insure permanency. In instruments where the magnetic field in which the armature turns is non-uniform, position error may result from the side play in the bearings which permits the armature to move sideways in the non-uniform field with consequent changes in torque for different positions of the instrument.

The maximum allowable error of this class, as specified in the American Standard C39.1, is 1% of scale length for portable instruments and 2% of scale length for switchboard instruments when the instrument is inclined 30° in any direction from the normal operating position. It therefore is important that the user maintain the instrument in essentially the normal operating position to obtain the maximum accuracy.

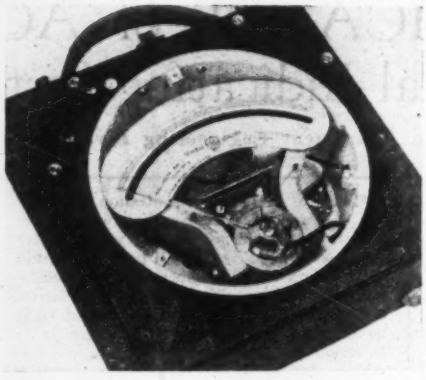


Fig. 2. G.E. Type DP-2 portable millivoltmeters with cover removed showing shield partly enclosing the element.

3. Effect of Electromagnetic Fields

Most electrical instruments operate on the principle of interaction of fluxes. A typical example is the permanent-magnet moving-coil type of d-c. instrument where the flux from the magnet interacts with the flux due to the current in the armature winding, causing the armature to turn on its axis. If an electromagnetic field is superimposed on the magnet's field, the strength of the latter may be altered and the accuracy of the instrument impaired accordingly. This error may be positive or negative depending on the relative direction of the two fields. In a-c. instruments a similar condition exists, except that the interfering field of either direct or alternating current may affect the accuracy. The three principal methods of reducing this error in electrical indicating instruments are as follows:

D-c. Instruments

1. Shield the element with a high-permeability magnetic material.
2. Use a self-shielding design of magnetic system.
3. Use a material for the magnet and a design of magnetic system which produce a high-strength useful field.

A-c. Instruments

1. Shield the element with a high-permeability magnetic material.
2. Wind field and armature coils astatically.

The shielded type of element consists of a shell or enclosure of a high-permeability magnetic material which partly encloses the element. A typical shielded element of a portable high-accuracy instrument, Type DP-2, is shown in Fig. 2. This method is effective but adds weight to the instrument.

In a field of five gausses (approximately equivalent to the field 12" from a conductor carrying 750 amperes) the error in a typical Type DP-2 instrument mentioned above is approximately 0.7% as compared to approximately 2.5% for the same instrument with no shielding. With the self-shielded type of magnetic element used in the General Electric Type DP-9 instrument, shown in Figs. 3 and 4, the error is approximately the same as with the shielded type. This latter design results in a lighter weight instrument which is of practical value in the portable types. This is made possible by

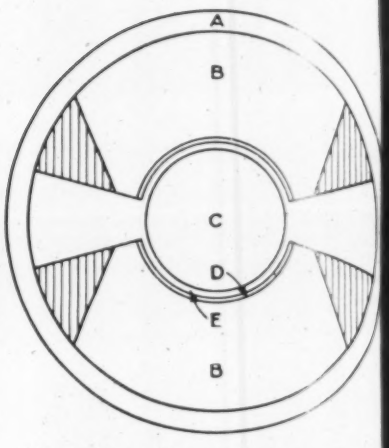


Fig. 3. Concentric-magnet system used in G medium sized portable instrument type DP-9.
A—Soft iron ring, return circuit for magnet fl and shield.
B—Alnico magnets.
C—Soft steel core.
D—Thin steel pole piece.
E—Air gap for moving coil.

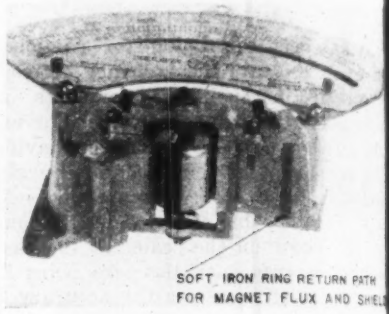


Fig. 4. G.E. Type DP-9, showing self-shieldi element.

the unique design of magnetic syste shown in Fig. 3, and the use of high coercive-force Alnico magnets.

In designing electrical instrument it is desirable to keep the strength o the fixed field as high as possible s that the effect of the interfering fiel will be minimized. This is done by us ing the correct relative dimensions o the magnet, length of air gaps, an proper selection of material for th magnets in the case of the permanent-magnet moving-coil type of instrument In a-c. instruments, one method of ac complishing this is by utilizing high-permeability magnetic material in th field circuit. Such a design is shown in Fig. 5.

It is possible to reduce the effect of external electromagnetic fields in some types of instruments by winding the coils astatically. In an electrodynamic type of voltmeter, for example, two potential coils may be used in the armature instead of one, and the coils wound opposite in direction so that voltages induced from an external field will be equal and opposite in the two coils and will cancel. The chief difficulty with this type of instrument is that it is usually larger and more complicated than other types using magnetic shielding. Therefore, few modern instruments are being made with astatic windings.

In using unshielded instruments on a switchboard it is, of course, necessary

Fig. 5. G.E. Type AP-9 portable wattmeter—cutaway view showing element construction.
A—Laminated field.
B—Field coil.
C—Armature.

to make sure that high-current conductors are not located sufficiently near the instruments to cause objectionable errors. In portable instruments, shielding is particularly important since they are more likely to be used in electromagnetic fields which may cause errors without the knowledge of the user. The maximum allowable error due to an external field of 5 gausses for different classes of instruments, as covered in A.S.A. Specification C39.1, are as follows:

Grade A Portable Instruments... 0.75%
Grade B Portable Instruments... 5.0 %

Switchboard Instruments

Metal case switchboard instruments of scale lengths of 2¾" and longer shall be shielded from magnetic fields. The error due to an external field of 5 gausses shall not exceed the following values:

All direct-current instruments.....1%
Alternating-current instruments:
Voltmeters having a scale length greater than 2¾" but less than 4½"...5%
Voltmeters and ammeters having a scale length 4½" and longer.....4%
Wattmeters 4%
Frequency Meters 2.5%
Power Factor Meters.....0.003p.f.

Magnetic shielding is not required for instruments having insulating cases.

Since d-c. instruments of this latter class will not read the same when mounted on magnetic as on non-magnetic panels, it is necessary to take this into consideration when applying these instruments. To eliminate this error it is customary to calibrate the instrument on the type of panel on which it is to be used.

Errors of this character may amount to as much as 6% for flush-mounted type instruments when used on a panel of magnetic material ⅛" thick if they are not calibrated accordingly. With a-c. instruments, errors due to the use of panels of magnetic materials are usually negligible.

When two or more unshielded instruments are used, they should not be placed close together so that their fields interact. For 3½" size permanent-magnet moving-coil type instruments a distance of at least 5" between centers should be maintained for instruments utilizing low-coercive magnets, and at least 8" for instruments utilizing high-coercive magnet materials. For the 2½" size, the distances should be 4" and 7" respectively if maximum accuracy is to be expected.

Correctly shielded instruments can, of course, be used in close proximity to each other and can be used interchangeably on magnetic or non-magnetic panels, without loss of accuracy.

4. Ambient Temperature Errors

The principal causes of ambient temperature errors in indicating instruments are:

1. Changes in resistance of the element circuits.
2. Changes in magnet strength of d-c., rectifier and thermocouple type instruments. (Ambient temperature errors in rectifier and thermocouple instruments will be discussed later.)
3. Changes in torque spring strength.

Changes in Resistance of the Element Circuits. Copper or aluminum wire is most commonly used in the moving coil and field coils of indicating instruments and the change in the resistance of these materials is approximately 0.4% per degree Centigrade, which means that if copper or aluminum were used throughout the circuit, for each change of 1°C. there would be an additional error of 0.4%. To reduce this error a material such as manganin or copnic, which has a low temperature coefficient, is generally connected in series with the armature. Over the usual temperature ranges the change in resistance of these materials is generally less than 0.003% per degree Centigrade. Thus, if the value of the resistance of the low-temperature-coefficient material which is used in series with the copper armature coils is three times the armature resistance, the overall temperature error will be approximately 0.1% per degree Centigrade. The ratio of the resistance of the low-temperature-coefficient material to the resistance of the armature is kept as high as practicable to minimize errors from this source.

Changes in Magnet Strength (Permanent-magnet Moving-coil Type Instruments). When the temperature of a magnet is increased the strength decreases. This decrease is usually of a temporary nature for moderate changes in temperature. For a typical magnet material the change in strength is approximately 0.025% per degree Centigrade change in temperature. The error due to the magnet is usually slightly smaller than that caused by the spring but is of such a direction that the two errors tend to cancel.

Changes in Spring Strength. As the ambient temperature is increased the torque of the control spring on the armature becomes weaker. This decrease in torque is in the order of 0.04% per degree Centigrade for a typical indicating instrument, as the temperature is increased. In d-c. instruments mentioned previously the resultant effect of the spring and magnet errors would be 0.015% per degree Centigrade. (In a-c. instruments the error due to the change in torque of the control spring is opposite in sign to the errors caused by changes in resistance of the element circuit.)

The resultant errors due to ambient temperature changes depend upon the overall balance of the various elements of the design and proper selection of constants for the circuits. It is that class of error which is not apparent to the user unless careful tests are made. The user must depend on the integrity of the manufacturer to keep these errors within reasonable limits.

Maximum allowable temperature errors, as specified by the A.S.A. (Spec. C39-1) for different classes of instruments, are given below:

Change in Indication as Percent of Full-scale Due to a Change of 10° C. from the Reference Temperature of 25°C.

Grade A Portable Instruments
0.2% for voltmeters
0.3% for ammeters operating from 100-mv. or 200-mv. shunts
1.0% for ammeters operating from 50-mv. shunts

Grade B Portable Instruments
0.4 % for voltmeters
0.5% for ammeters operating from 100-mv. or 200-mv. shunts
1.5% for ammeters operating from 50-mv. shunts

D-c. Switchboard Instruments
0.35% for instruments having one or more voltage circuits
1.0% for instruments having one or more current circuits

A-c. Switchboard Instruments
0.25% for ammeters, voltmeters, and wattmeters
0.35% for frequency meters
0.005p.f. for power factor meters

5. Electrostatic Effects

An electrostatic charge on the glass window (usually set up by rubbing) may cause the pointed to deflect a considerable distance from its correct position. Such a charge can usually be dissipated by "breathing" on the glass. Plastic windows, unless made of special static-free materials or materials specially treated, may cause excessive electrostatic-effect errors: it frequently is difficult and sometimes impossible to remove the charge on plastic windows without removing the window and "breathing" on it or using a similar means to remove the charge on the inside surface. A single spot on the window may become charged with the remaining area clear of any charge. Once more the user must depend upon the manufacturer to use a material and so treat it that this effect, if present, can at least be removed as easily as from a glass window.

6. Self-heat Errors

In the operation of electrical instruments heat is dissipated by the instrument to an extent depending on the type and design of instrument. The heating in a milliammeter for example is usually small, whereas in a high-rated self-contained ammeter or high-voltage low-resistance voltmeter the

heating is considerably higher. The effect of this heating on the accuracy of an instrument depends upon the design of the electric circuit, sensitivity of the element, relative position of the heat-generating parts, and the material used in the case. When these factors are given proper consideration the final instrument should, where the self-heat effect is sufficient to affect the accuracy, be calibrated under such conditions as to average the effect of the heating errors. This may be done by maintaining the instrument at a given scale point for a sufficient time before calibration so that the errors due to self-heat are properly balanced for the different points on the scale. Maximum allowable errors due to self-heat for portable instruments, as covered in A.S.A. Specification C39.1, are as follows:

Portable D-c. Voltmeters and Ammeters: Grade A, 0.1%; Grade B, 0.2%.

Portable A-c. Voltmeters and Ammeters: Grade A, 0.2%; Grade B, 0.5%.

Portable Wattmeters: Grade A, 0.1%; Grade B, 0.5%.

Grade A Portable Frequency Meters, 0.1%.

7. Effect of Changes in (power) Frequency (A-c. Instruments)

For a-c. instruments designed for use on power frequencies the principal errors due to changes in frequency result from changes in the reactance of the element circuits, permitting more or less current to flow (depending on whether the frequency increases or decreases) and consequently changing the torque. To minimize this effect a resistance is usually connected in series with the element in the potential circuit. This resistance is usually made large as compared to the reactance, to "swamp out" changes in reactance.

In modern design of instruments the errors due to normal variations in frequency are usually negligible. Maximum allowable errors as given in A.S.A. Specification C39.1 for a departure of ±10% of rated frequency are as follows:

A-c. Portable Instruments	0.5%
A-c. Switchboard Instruments (except Frequency Meters and Single-phase Power Factor Meters)	0.5%

8. Effect of Changes in Voltage on the Accuracy of Wattmeters, Frequency Meters, Temperature Indicators and Power Factor Indicators

Errors in wattmeters and varmeters due to changes in voltage over the normal operating range of voltage should be negligible in well-designed instruments. However, with wide excursions beyond either end of the operating range, errors may result from the consequent variations in self-heating conditions and, in the case of iron core instrument systems, due to non-linear behavior of magnetic circuits. These errors are, however, usually unimportant. In instruments which employ the ratio principle such as frequency and power factor meters and some forms of temperature indicators, variations in voltage may produce errors due to disturbance of the ratio of the current in two or more of the instrument circuits. Errors in instrument indication may also result if the torque of the lead-in spirals on the armature is excessive due to incorrect design. Errors of this type may be either positive or negative, and also vary in magnitude at different points on the scale.

The maximum allowable errors due to variations of ±10% in voltage as covered in A.S.A. Specification C39.1 are as follows:

Portable Wattmeters	0.25%
A-c. Switchboard Instruments (Over the measurement range)	
Wattmeters	0.5%
Frequency Meters	0.25%
Power Factor Indicators	0.005%

9. Effect of Wave-form on the Accuracy of A-c. Instruments

Errors in a-c. indicating instruments due to departures of the wave-form from that of a sine wave vary considerably with the design of instrument. For a number of years the electrodynamic type of a-c. instrument was to be preferred from the standpoint of low wave-form errors. With the advent of the high-permeability magnetic materials, however, the magnetic-vane type of instrument has been developed to a point where it is entirely satisfactory. In the higher rated ammeters, the overall performance is probably superior. A portable voltmeter utilizing high-permeability magnetic materials for the vanes is shown in Fig. 6. (The wattmeter shown in Fig. 5 utilizes a similar material in the field circuit.)

Fig. 6. Element for G.E. Type P-3 ammeter. a—High-permeability armature vanes. b—Internal shield.

With the exception of the rectifier-type instruments discussed below, instruments of modern design are in general reasonably free from errors due to wave-forms generally encountered in commercial power circuits.

THERMOCOUPLE- AND RECTIFIER-TYPE INSTRUMENTS

While it is not within the scope of this discussion to cover instruments for special applications, the importance of thermocouple- and rectifier-type instru-

(Continued on page 652)

"Multiple-diaphragm Pressure Regulators and Their Application"—*Erratum*

On page 530 of our September issue the long double equation near the bottom of the page (just above Fig. 11) was a misprint. It should read as follows:

$$P_1A_1 + P_4[(A_1 + A_2) - A_1] = P_3A_2 + P_2[(A_1 + A_2) - A_2]$$
$$P_1A_1 - P_2A_1 = P_3A_2 - P_4A_2$$

This correction has been made in the reprints, available from the author, H. C. McRae, North American Mfg. Co., 2910 East 75th Street, Cleveland 4, Ohio. (No reprints available directly from *Instruments*.)

"Industrial Temperature Instruments Employing Electronic Devices"—*Addendum*

[Talk by C. O. Fairchild before Society for Measurement and Control (New Jersey), June 6, 1944; published in *Instruments*, August 1944, pages 468-472, 496.]

DISCUSSION AND CLOSURE

W. H. STEINKAMP (Assistant General Sales Manager, Brown Instrument Co.).—I would like to call to the attention of Mr. Fairchild and the Society members an error in his description of the Brown Electronik Potentiometer. Mr. Fairchild stated that it is necessary to use shielded extension lead wires to protect against strays. This is incorrect as it is not necessary to use shielding of any kind. Several thousand of these Brown Electronik Potentiometers are now in service and have been for periods as long as three years, all using standard extension leads and without any form of shielding.

C. O. FAIRCHILD.—I erred in saying that "shielding" is necessary. What should have been said is that "either shielding or filtering" is necessary. Obviously, the latter is available only for limited speeds of operation but is apparently quite adequate for the major purposes for which the Brown Instrument Company is marketing the instrument.

Toward Improving the Utility of the A.S.M.E-A.G.A. Orifice Coefficients

By THEODORE F. FALLS and GEORGE B. BAILEY
Consulting Engineer* The Hays Corporation

THE orifice coefficients prepared by the A.S.M.E.-A.G.A. Joint Committee in conjunction with the Bureau of Standards represent one of the most extensive studies of empirical values in general engineering use today. It is a job well done, on the whole, especially the presentation of basic theory. The decision to publish the uncompleted work of Edgar Buckingham was unique and constructive; and it is in the spirit of their solicitation of contributions in this field that the following suggestions are offered.

The greatest (and probably unexpected) complaint with regard to the general scheme of the coefficients is the presentation against R_d (Reynolds Number with respect to orifice diameter). Because of this form, design of an orifice becomes a process of cut-and-try selection of orifice diameter, coefficient and corresponding Reynolds Number until coincidence is achieved. It entails at least one check-back and, in the case of low Reynolds Numbers in the turbulent region, sometimes two or even three recomputations.

SOLUTION FOR ORIFICE DESIGN.

More specifically, the problem of orifice design consists of solution of the typical equation

1) $$w = 0.0997 K D_2^2 (h\rho)^{1/2} \dagger$$

where
w = flow rate, lbs./sec.,
D_2 = orifice diameter, in.,
h = differential, inches of water column,
ρ = density of flowing medium, lbs./cu.ft.,
$K = C/(1-\beta^4)^{1/2}$, orifice coefficient, including velocity-of-approach factor,
β = orifice ratio: D_2/D_1,
D_1 = pipe diameter, inches.

From known values of the installation a numerical evaluation of KD_2^2 can be determined. Collaterally an expression for Reynolds Number is set up, such as

2) $$R_d = 15.28\, w/(\mu D_2),$$

where μ = viscosity, lbs./sec.-ft.
This is evaluated in terms of D_2, taking the form

2a) $$R_d = k/D_2.$$

Now begins the hunt for a value of D_2 such that K corresponding to the value of R_d from equation 2a satisfies the requirement of KD_2^2 from equation 1. Some orifice computers become very skilful at it.

A substitution in widespread use derives from

3) $$D_2 = \beta D_1,$$

whereby equation 1 becomes

4) $$w = 0.0997 \beta^2 K D_1^2 (h\rho)^{1/2}$$

This equation is solved for $\beta^2 K$. Use is made of prepared tables of $\beta^2 K$ for various values of β against R_d, a sound and theoretically rigorous step. This is a great improvement, for it eliminates computation of β; but it leaves the computer still with the problem of finding coincidence between R_d, now appearing in the form

5) $$R_d = k_1/\beta,$$

and the position of $\beta^2 K$ in the table for the proper pipe size.

This is the present stage of the art as indicated by published material.

WHY NOT R_D?

The next step forward is inherent in equation 5, of which k_1 is in reality R_D —Reynolds Number with respect to pipe diameter. This is the rigid relationship for non-compressible fluids (liquids) derived by other means. It is equally true for the compressible gases in terms of w, since adiabatic temperature changes are hardly sufficient to affect μ, if indeed the condition could be evaluated in the plane of the orifice.

It is submitted that the orifice coefficients K, and the derivation $\beta^2 K$, can be ranged against R_D with a resulting major convenience in orifice design, no loss of precision within the present accuracy of the data, and without loss of effectiveness in other operations for which the coefficients are intended.

The operation of orifice design now becomes direct:

(a) Solution for R_D with the equation

6) $$R_D = 15.28\, w/\mu D_1;$$

(b) Solution for $\beta^2 K$ in equation 4;

(c) Immediate identification of β in a table of $\beta^2 K$ vs. β for values of R_D;

(d) Computation of D_2 from equation 3.

IS R_D SOUND?

The theoretical preciseness of the use of R_D with orifices can be debated profitably. It can be rigorously derived within the empirical equations that Buckingham completed, and hence proves satisfactory when checked against the coefficients he computed from them. Direct trial indicates a similar suitability in the categories which did not yield to his efforts and hence were taken directly from experimental data. Our analyses were limited, of course, to the generally circulated Fluid Meters Committee Reports—the Theory (4th Ed., 1937) and the History.

One matter of great importance develops when we appreciate the interrelationship of R_d (orifice diameter) and R_D (pipe diameter). This is the fact that we have not been recognizing that line conditions may fall in the transitional or even in the viscous region for apparently safely turbulent orifice velocities. The fault develops in the lower β values and low R_d numbers. Other evidence would lead us to suspect that turbulence will not develop at all, or only partly, in a jet of turbulent rating coincident with stabilized viscous line flow.

Certainly, the fluctuating line pressure that frequently occurs in the transitional region for the pipe should upset all orifice coefficients, regardless of the Reynolds Number in the jet (or at the entering edge of the orifice). This matter requires careful experimental study, or a re-examination of previous basic experimental work.

The other major service of the coefficients is to interpret differential pressures in terms of discharge rates for orifices cut and installed. Reynolds Number is again a variable, for velocity is a variable. A little thought will reveal that there is no advantage of convenience in either over the other, in selecting the coefficient. Both R_D and R_d are linear with velocity, the only unknown in this case. There are possibilities of improving the process of computation, as will appear later, but these are independent of the base for Reynolds Number.

INVERSE OF REYNOLDS NUMBER OPENS EVEN GREATER POSSIBILITIES.

Turning now to Flange and Corner Tap coefficients in particular, we wish to point out another possibility heretofore overlooked, but inherent in the work of Buckingham. These coefficients, a curve when plotted against R_d or R_D (or their logs), and consequently troublesome to interpolate, are actually hyperbolic, and hence linear when plotted against the inverse of either Reynolds Number! This is true well within the scope of precision of the coefficients published in the two sources mentioned above, and for all values of β and all listed pipe sizes.

In making the analyses which led to these conclusions, it was found that $10^5/R_D$ offered greater convenience, since it avoids the extensive decimal notation of the number $1/R_D$. The new "Reynolds Factor" relates to the well-understood points of Reynolds Number as follows:

*Recently with Askania Regulator Co.
†A.S.M.E.-A.G.A. Committee nomenclature is followed wherever possible, throughout this article.

Reynolds Number	$10^5/R_D$	
∞	0	(ultimate)
100,000	1	
3000	33.3	(Lower turbulent limit)
2150	46.5	(Upper viscous limit, prox.)

The linearity of K vs. $10^5/R_D$ yields some interesting corollaries. The straight line equation becomes, for each value of β within each pipe size:

7) $$K = K_0[1 + a(10^5/R_D)]$$

K_0 is the intercept of the new form and the asymptote of the form currently in use. In other words, it is K for infinite Reynolds Number and for zero Reynolds Factor. It varies with β and with pipe size, and is common for $10^5/R_D$ and $10^5/R_d$. No analysis was undertaken to evaluate the trends, as this is covered by Buckingham's equations.

The slope factor a shows a remarkable systematic trend with β for a given pipe diameter, and all pipe diameters; and with D_1 for constant β and for all values of β. It would appear that a little further analysis will yield complete correlation.

Recent theoretical advances indicate some other possibilities of analysis which may yield a direct solution for the slope and diameter curves, but it is desirable to go back to the experimental data for this, since Buckingham's calculations are apt to be warped by his approximations in setting up his equations.

With tables of K_0 and a available, the problem of calibrating an orifice is simplified. β is fixed by D_2 and D_1, and K_0 and a by β and D_1. Hence equations 6 and 7 may be substituted in equation 4:

8) $$w = 0.0997\,\beta_2 K_0 \left(1 + a\,\frac{10^5 \mu D_1}{15.28\,w}\right) D_1^2 (h\rho)^{1/2}$$

Evaluating known quantities:

8a) $$w/[k_1(1 + k_2/w)] = h^{1/2}$$

A schedule of w vs. h may be computed from this directly, once the lower turbulent limit is determined in terms of w.

The Vena Contracta Tap coefficients were examined from the same standpoint. The plots of K vs. $10^5/R_D$ for various values of β and of D_1 do not yield the same linear system, but are apparently an equally systematic set of regular curves. It would be out of place, perhaps, to record our guesses, but it is important to note that there is promise, once the general shape characteristics of the curves are determined, that the cross-analyses will prove as consistent as do the Flange Taps.

No study was made for Pipe Taps, or for Radius Taps.

The foregoing is intended to suggest wholly conventional alterations in the presentation of orifice coefficients, toward their more widespread utility. It describes certain useful analyses, without undertaking to develop and support these analyses formally, partly because the work was perforce "second-hand" and not based on experimental data directly, and partly because it is desired to bring forward other discussion of the subject.

* * *

The authors wish to acknowledge the importance of the collaboration between Askania Regulator Company and The Hays Corporation in this technical matter. Without this collaboration, relatively little of this work would have been completed.

Calculator Computes I^2R Quickly

By V. W. PALEN, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

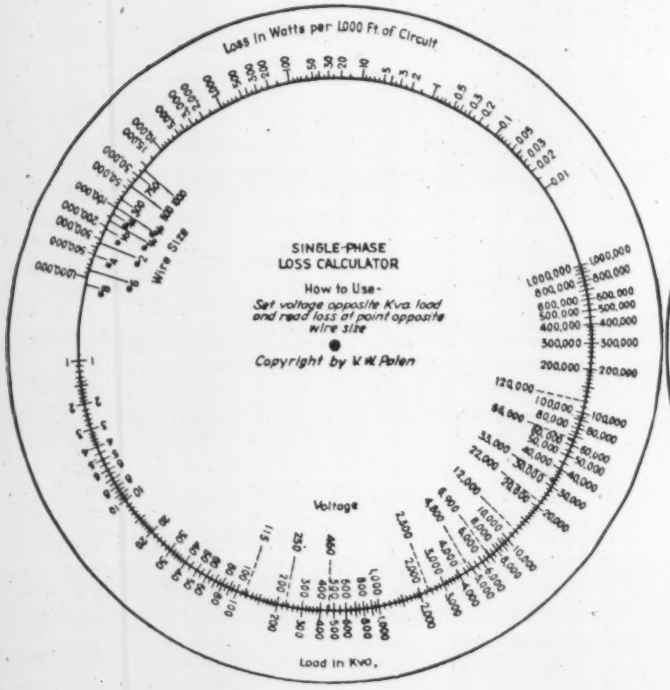
HERE'S a device which determines I^2R loss in wire circuits with a flick of the finger.

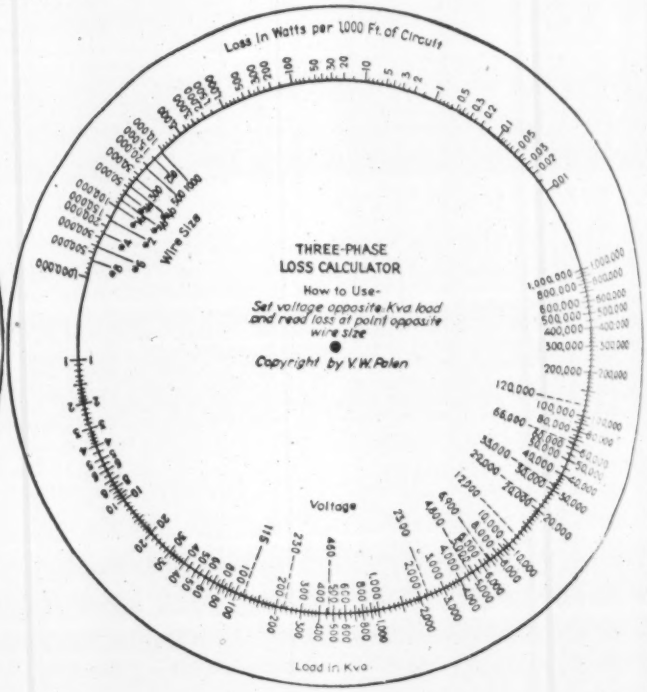
Cut along the circles to make two disks and two rings. Using rubber cement, mount the disks on separate pieces of cardboard; then, mount the two rings on reverse sides of a *third* piece of cardboard. Now punch the center holes and insert a small brass bolt to hold the disks in place. Washers will help to prevent wear and tear on the paper. Tighten the bolt to provide the proper pressure on the disks: they should hold their settings, yet turn easily. A drop of solder applied to the nut will make the assembly permanent.

The calculator solves the single phase equation:—

$$(\text{Kva}/\text{Kv})^2 \times 2R = W$$

where R is resistance of 1000 ft. of single conductor and W is watts per 1000 ft. of circuit. The three-phase equation handled by the device is equivalent to the single-phase relationship divided by two. Copper conductor is, of course, the basis of design—stranded on sizes #2 and larger.


Loss in Watts per 1000 Ft. of Circuit
Wire Size
SINGLE-PHASE
LOSS CALCULATOR
How to Use-
Set voltage opposite Kva load and read loss at point opposite wire size
Copyright by V.W.Palen
Voltage
Load in Kva.


Loss in Watts per 1000 Ft. of Circuit
Wire Size
THREE-PHASE
LOSS CALCULATOR
How to Use-
Set voltage opposite Kva load and read loss at point opposite wire size
Copyright by V.W.Palen
Voltage
Load in Kva.

ELECTRIC GAGING METHODS for Strain, Movement, Pressure and Vibration

By HOWARD C. ROBERTS, University of Illinois

V. GAGING METHODS BASED ON VARIATIONS OF RESISTANCE.

(Concluded)

§4. STRAIN-AND-PRESSURE-SENSITIVE RESISTANCE ELEMENTS. A change in dimension of an electrical conductor will cause a change in its resistance. This is necessarily true, since an increase in length increases resistance, while an increase in cross-sectional area decreases it.

If the dimensions are changed through the application of a force, the resistivity of the material is usually changed likewise, because of the internal stress.

For a round wire having a Poisson's ratio of 0.3 it may be shown that if the length is increased by 1.0% through an applied force, the change in resistance should be 1.7% due to change in dimension alone. Of this amount, part is due to increase in length, part to decrease in cross-section. By actual experiment, however, it is found that the change in resistance may be as little as 0.5% or as great as 5.0%, depending upon the material.[163] The difference between the experimental figures and the value computed from geometrical factors represents the change in resistivity.

Usually, a material sensitive to linear strain is sensitive also to applied hydrostatic pressure; the two effects are called respectively strain-sensitivity and pressure-sensitivity. The effect appears to be somewhat larger for small sizes of conductors than for larger sizes. For the small wire sizes in commonest use, the precise values for Poisson's ratio and for the compressibility have not yet been determined.

Application of the principle to the measurement of liquid pressures was a direct and obvious consequence of the discovery of the property. (Historically, it appears that early interest in the problem was aroused at the time the first submarine cables were planned.[164] Academic research was in progress before this time; it was realized even then that the effect was due to change in *properties* of the metal as well as change in dimension.[165]) Such pressures as are encountered in extremely high-pressure research can best be measured with a resistance-type gage.[166]

The sensitive element employed in pressure measurement is ordinarily a helically-wound coil, mounted on a suitable form and protected by insulating lacquer from the liquid in which it is immersed. Since the effect of the pressure is exerted on the winding form and on the lacquer as well as on the wire, care must be taken in the design of the assembly to insure that deformation of these parts does not deform the wire coil. Precautions must be taken, too, in bringing the connecting leads out of the pressure chamber, and in the selection of materials and the operation of the instrument to minimize errors due to changes in temperature. The change in resistance of most materials due to a few degrees change in temperature is as great as that from fairly high pressures. To reduce this error, manganin wire is ordinarily employed in winding the coil; manganin has an extremely low temperature coefficient of resistivity. Such gaging devices must have their calibrations checked by experiment to eliminate the errors from differences in construction.

(163) A. V. deForest. Characteristics and Aircraft Applications of Wire Resistance Strain Gages. *Instruments*, Vol. 15, 1942, pages 112-114, 136-137.

(164) Elie Wartmann. On the Effect of Pressure on Electric Conductibility in Metallic Wires. *Philosophical Magazine* (London), Vol. 17, Series 4, 1859, pages 441-442.

(165) William Thomson. On the Electrodynamic Qualities of Metals. *Philosophical Transactions of the Royal Society* (London), Vol. 146, 1856, pages 649-751.

(166) P. W. Bridgman. Theoretical Considerations on the Nature of Metallic Resistance, with Especial Regard to the Pressure Effect. *Physical Review*, Vol. 9, Series 2, 1917, pages 269-289.

Although the application of the principle of stress-sensitivity to the measurement of pressure is simple and direct, requiring only exposing the wire to the hydrostatic pressure, the measurement of force, movement or acceleration requires that the strain-sensitive resistance elements be installed in some manner in which they are subjected to the mechanical magnitude to be measured. The measurement of forces or movements by the direct application of the phenomenon to a conducting element is subject to the difficulty that only tension can be applied to a wire element, and also that the movement permissible is limited by the elastic constants of the material. In general, therefore, the application must be indirect.

In a direct application of the principle to the measurement of acceleration, a mass suspended by fine wires in three mutually perpendicular directions experiences a force proportional to the acceleration applied, and the elastic suspension wires in turn experience strain proportional to the force. These elastic suspensions are themselves the resistance elements. Thus the acceleration is represented as a variation in resistance—in fact, as the variations in resistance of three elements, so that the directional components of the acceleration are resolved at the same time the measurement is made.[167] Since for mechanical reasons it is desirable to maintain tension in these suspensions when the system is at rest, and since each is in construction a pair of opposing suspensions, push-pull operation is convenient. The gaging element then is a resistance-ratio type.

Stretched metallic wires have been employed also in gages for measuring strain and pressure. One form which has had a wide application for engineering use employs fine steel wires wound in tension on a two-piece insulating support, in such a manner that movement of one portion of the support decreases the tension in one coil while increasing it in the other.[168] The movement is introduced either by the action of a diaphragm to which fluid pressure can be applied, or by attachment of the two parts of the insulating former to the member undergoing strain. In order to simplify the mechanical construction, a three-coil assembly is ordinarily employed, two coils being opposed to a third which is equal in resistance to the sum of the first two. The assembly is shown in Fig. 73. As ordinarily used,

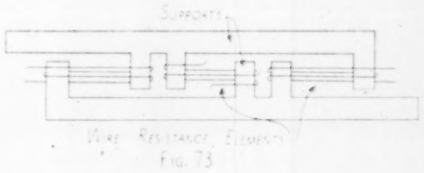


Fig. 73

the instrument has a rather high temperature coefficient, so that it is necessary to measure the temperature at the time of each reading and apply a correction. A separate unstressed winding can be installed in the gaging element, or the windings employed for strain measurement can in a different circuit be used as a resistance-thermometer winding.[169]

By far the most extensive application of strain-sensitive electrical resistance elements has been in the form of resistance-strip strain gages. These gages, although available in many different mechanical forms, are simply strips or

(167) G. Gerloff. Ueber einen neuer Beschleunigungsmesser und Einschwingvorgaenge bei Schwingungsmessern. *Forschung auf dem Gebiete des Ingenieurswesens*, Vol. 8, 1937, pages 143-152.

(168) E. C. Eaton. Electric Resistance Gage. *Engineering News-Record*, Vol. 107, 1931, pages 615-616.

(169) R. W. Carlson. Five Years Improvement in the Elastic-wire Strainmeter. *Engineering News-Record*, Vol. 114, 1935, pages 696-697.

wafers of material which may be attached to any convenient surface, and which contain electrical resistance elements having known resistances and known strain sensitivities. The resistance elements may be made of wire, of carbon composition, or of metallic films.

The photograph, Fig. 74, shows several different mechanical forms of resistance-strip gages. In the background appears a lead pencil for comparison of size. At the left are three gages made with carbon-composition resistance elements; they have base-lengths ranging from ⅜" to 1" and resistances ranging from 1,000 to 10,000 ohms. These gages are available with base-lengths as short as 1/16" or

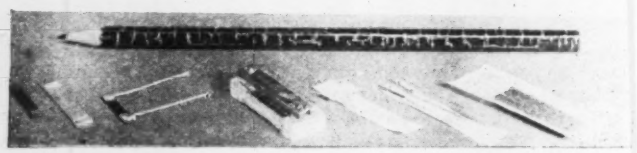


Fig. 74. Resistance-strip Strain Gages.

as long as several inches, and their resistances can be made as low as 10 ohms and as high as 50,000 ohms. The five gages at the right of the picture are wire-type resistance-strip gages. Their base-lengths range from ¼" to 1", and their resistances from 120 to 500 ohms. These gages, too, can be constructed in lengths from ⅛" to several inches, and with resistances ranging from only a few ohms to several thousand.

In all such resistance strip gages, there must be present some insulating supporting material, to which the strain-sensitive conducting material is attached, and to which the electrical terminals can be affixed. This insulating support forms the body of the gage, and is itself attached to the specimen by an adhesive. When so attached, the gage experiences the same change in dimension as the specimen, and this change in dimension changes the resistance of the enclosed element correspondingly.

The perspective sketches in Fig. 75 indicate the manner of construction of the several forms of resistance strip gages shown in Fig. 74. In Fig. 75A, the insulated or enclosed form of the carbon-type resistance-strip gage is shown. This gage is a molded product, made of several layers of cloth-reenforced plastic for mechanical strength, with a narrow strip of conducting material molded within the assembly. Electrical contacts are made at the ends through narrow strips of wire gauze molded into the gage in contact with the resistance element. To these wire gauze contacts the lead wires can be soldered after the gage is installed. This gage is mechanically quite robust, and is easily applied and removed. Excepting at the ends where the contacts are brought out to the connecting wires, it is enclosed entirely within insulating material, and the danger from insulation leakage is greatly reduced.

In Fig. 75B is shown the uninsulated carbon-strip gage. This gage is ordinarily a thin strip of bakelized paper (or similar material) with one surface coated with a carbon compound having the desired resistance and strain-sensitivity. At the two ends electrical contacts are provided by sprayed-on copper or silver terminals, and soldering wires to these. Nearly all of the surface of the resistance material is exposed. This gage has been widely used, and is quite convenient and flexible in its application, but is much less robust in use than the form of Fig. 75A. Since most of the carbon resistance element is exposed to atmospheric disturbances and to possible mishandling, and since the leakage paths from the resistance element to the specimen are short, great care must be exercised in installing and using such gages. Insulating varnishes and waterproofing compounds have been effectively applied to such gages.

These are not the only forms of carbon-type strip gages, but they are the most popular ones. Some of the available gages are thin wafers of solid carbon composition with attached terminals at the ends; these must be installed (if on metallic surfaces) with a layer of insulating material separating the gage from the specimen. In some applications, gages of this sort have been made from molded carbon resistors ground down to the desired shape; in others the cylindrical resistor elements are installed in such manner as to take the applied force in compression. In the early work with resistance-strip gages, some of those used were made up *in situ* by attaching insulating paper strips to the specimen and applying carbon films to these paper slips. [171, 172] More recently, carbon gages having special characteristics have been constructed; one of the most interesting of these is the so-called "stress gage" in which

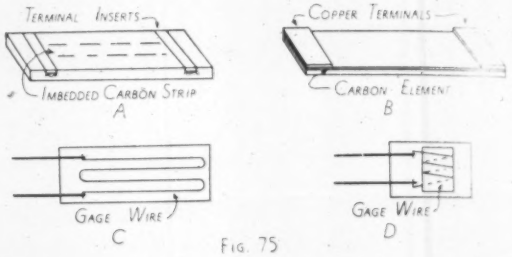


Fig. 75

transverse sensitivity is deliberately installed to a prescribed degree. The intent is to provide an indication proportional to total stress in the specimen, rather than linear strain.[173]

All presently-used gages in which the resistance material is applied in the form of a flat sheet or a wire grid have some transverse sensitivity—that is, change in width of gage will change its resistance, just as will change in length, although in general not to the same degree. Since a strain in one direction is ordinarily accompanied by another strain of opposite sign at right angles (the Poisson effect) this transverse sensitivity can and does introduce error except in special cases. In fields of combined stress these factors must be carefully considered; no universally applicable gage is at present available.

In Fig. 75, C and D show the two common forms of wire assembly for resistance strip gages. In C the wire is disposed in the form of a grid, zig-zagging back and forth along the length of the gage, with the spacing between adjacent wires carefully maintained. In D the helical form is shown; here the wire is wound on a flat thin slip of paper, in the form of a flattened helix, and this helix is then mounted between two larger pieces of paper. In both assemblies the fine wire forming the strain-sensitive element is attached to heavier wires installed as electrical terminals; these are more easily handled and less liable to damage than the fine gage wires.

The base-length of the wire gage may be made as short or as long as desired, within the limits imposed by constructional difficulties. In order to maintain the desired total resistance, a sufficient length of wire must be installed; if the base-length is made too short, the gage will become extremely wide; as a compromise method, special means for maintaining wire spacing and insulation are employed. A flat helical winding on an insulating card is one such means.

In the construction of wire-type resistance-strip gages, it is customary to employ wires of about 0.001" diameter, and of some material having a low thermal coefficient of resistivity. Alloys of the constantan type are frequently used. Their characteristics are favorable to the application —they are easily assembled, the wire has a high ductility and can be drawn into fine uniform wires, and the material

(170) P. J. Rigden. The Properties of Carbon Resistor Elements with Particular Reference to their Behavior Under Steady Loads. *Journal of Scientific Instruments* (London), Vol. 19, 1942, pages 120-123.

(171) A. Bloch. New Methods for Measuring Mechanical Stresses at Higher Frequencies. *Nature* (London), Vol. 136, Aug. 10, 1935, pages 223-224.

(172) E. H. Hull. Alternating Stress Measurement by Resistance Strip Method. *General Electric Review*, Vol. 40, 1937, pages 370-380.

(173) S. B. Williams. The Dyadic Gage. *Proceedings of the Society for Experimental Stress Analysis*, Vol. 1, No. 2, 1944, pages 43-55.

is stable. The low temperature coefficient of resistivity is a convenience, but not a real necessity; the same is true of the relatively high resistivity.

The supporting material employed is thin paper, having good mechanical and insulating characteristics. The adhesive with which the gage is assembled varies with the application; when possible it is convenient to employ a cellulose-base lacquer or cement. Such a cement is quick-drying and easily used. Occasionally it is desirable to construct the gage directly on the specimen.

Such a gage has an extremely small mass, and is sufficiently flexible in construction to permit application to curved surfaces. Because of the delicacy of construction, the gage is easily damaged before installation; care must be exercised to prevent such damage. After installation, protection from mechanical damage and from moisture must be provided, just as with other gages. The inertia of the gage is small because of the small mass, and the forces developed by applied accelerations can never be very large. In fact, the mass of the terminal wires is greater than that of the rest of the gage.

Both carbon and wire-type resistance-strip gages offer some restraint to the movement actuating them, since in order to produce a strain in the gaging element some force must be applied. And since this force must be transmitted through the adhesive with which the gage is attached, the adhesive becomes a part of the gaging element assembly—the pick-up—and its characteristics must be so considered. The same is true of cement employed in gage construction.

The primary criterion to be employed in the selection of the adhesive and the insulating material to be employed in a resistance-type strain gage is this: Does it insure that the strain experienced by the gaging element is identical to that experienced by the specimen, regardless of the magnitude of that strain, of time and temperature, and of other operational conditions?

Resistance-strip gages are intended to be applied to a specimen or structure and to measure strain only. Any other magnitude to be measured must be converted to strain and then measured indirectly.

Force is measured in terms of the strain produced in a weighbar, pressure by the strain in a diaphragm, and acceleration by the strain produced in an elastic member flexibly supporting a mass. Some ingenuity is required in the construction of these devices for converting other magnitudes to strain, but in general the applications are quite

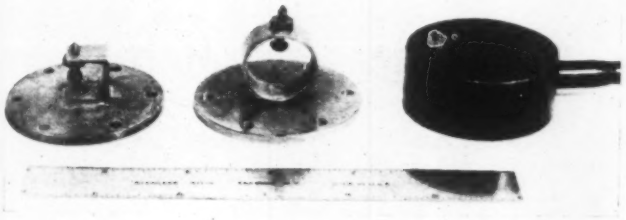


Fig. 76. Pressure-cell Construction.

straightforward. In Fig. 76 are shown the elastic steel members used in a series of pressure-measuring cells, and one completed cell, waterproofed. One is a cantilever-beam form, the other is a ring-type dynamometer; both perform well. The resistance-strip gages are installed at points on the elastic member where strain occurs; on the cantilever-beam model two gages are used on the two sides of the beam, one experiencing tension at the same time the other is in compression. In the ring-type model four gages can be employed if desired. In all instances of such installation it is desirable to employ two (or four) gages in opposition, connected as resistance-ratio gages. In this manner sensitivity is increased and temperature compensation provided.

In any application in which only one resistance element is employed, unless it is a resistance-ratio element, large errors may occur from temperature drift. An *installed* gage will suffer a change in resistance with temperature, even though the gage alone has a zero temperature coefficient; this follows from the fact that the specimen on which the gage is installed has a thermal expansion characteristic, which will cause the dimensions of the gage to change with temperature. By the use of a compensating gage, or a resistance-ratio gage, this error can be completely compensated.

Compensation for temperature change, and for lead-length error, is extremely important with resistance-strip gages and with all others depending upon stress-sensitivity, because of the small change in resistance of the gage with applied strain. In most applications, the maximum change in resistance due to applied strain will be less than 1%—it may be only a small fraction of that 1%. For accuracy, therefore, small changes in resistance must be avoided. Detailed consideration of this item will be reserved for a later section.

Resistance-strip strain gages, of either the carbon type or the wire type, are capable of responding to extremely high mechanical frequencies; they have been successfully employed at frequencies of the order of 50,000 cycles per second. The upper limit of frequency response of such a system is dictated not by the gage element but by the associated electric circuits and recording devices.

§ 5. Miscellaneous Forms of Variable-Resistance Gaging Elements

Of the many miscellaneous resistance-type gaging devices, most have been based upon principles not widely known and upon effects of small and uncertain magnitude. Few have achieved satisfactory application in more than one installation. There are, however, three variable-resistance gaging methods which belong in this category and which deserve description, either because of their wide use or their particular capabilities.

The first to be described is based upon the fact that the ohmic resistance of many materials varies with the strength of the magnetic field in which they are placed.[165] Of these metals, bismuth is most applicable to measurement uses, since it shows the effect to the highest degree and likewise has the highest stability of those known. The principle has been applied to physiological measurements, and also to the measurement of magnetic field strength in electrical engineering.[174] Such a device can also be effectively used in conjunction with the plate-thickness gage illustrated in Figs. 44 and 61 of this work.

Another is a variable-resistance element in which a thermally-operated contactor interrupts a circuit periodically, thereby changing the average amount of current flowing.

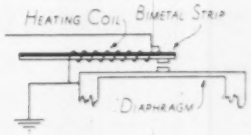


Fig. 77

Its construction is illustrated in Fig. 77. The wire coil surrounding the bimetallic strip is a heater element; as current flows through this element the bimetal strip is heated and bends; when it has bent until it touches the contact attached to the diaphragm the heater element is shorted out and cools. As it cools, it straightens, opens the circuit, and the cycle begins again. In operation the cycle requires less than one second for completion; the exact value depending upon the distance to which the bimetal strip must bend to close the circuit. The current flowing is an interrupted direct current; its average value is proportional to the distance which the bimetal strip must move. Any suitable instrument may be used to measure the current; usually a thermal device is preferable, because of its simplicity, ruggedness, and its ability to average the current.

(Continued on page 626)

(174) G. S. Smith. Bismuth Bridge Magnetic Flux Meter. University of Washington Engineering Experiment Station Bulletin No. 93, Nov. 1940.

ELECTRON TUBES—Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER, Managing Editor, *Power Plant Engineering*, Chicago, Ill.

XXIV. TUBE DATA

As was pointed out in the preceding article, the great number of tube types listed in the tables need cause no confusion if we remember that all tubes can be grouped into a comparatively small number of classifications either according to function or cathode-filament voltage. One should make it a point to become reasonably familiar with the tables in order to derive the greatest possible use from them; they really contain a great deal of useful information. Tables of tube characteristics are listed in various handbooks, one of the most complete being that in the 1944 edition of the Radio Amateur's Handbook, published by the American Radio Relay League.

The tables give the maximum ratings for the various types of tubes listed as well as much other pertinent data involving their application. In the interest of long tube life, filament or heater voltages should always be maintained as nearly as possible at the rating given (variations not more than 5% *either above or below* rated voltage) and the

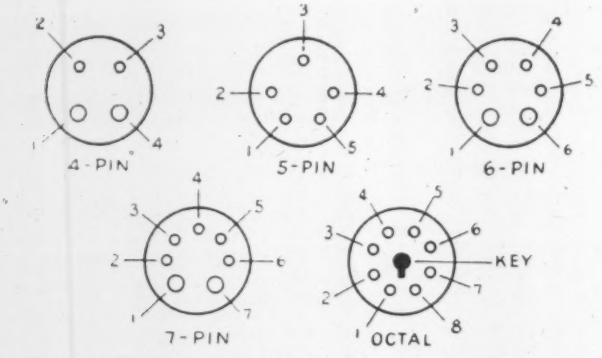


Fig. 166. Tube base pin numbering system. These drawings show the pins looking at the bottom of a tube base or socket. Pins are numbered in a clockwise direction starting with the left cathode pin as No. 1 with glass tubes but with the shield pin as No. 1 with the metal tubes. The metal tubes are characterized by the octal base. On the 4-, 6- and 7-pin bases, the cathode pins are heavier than the others.

maximum plate-supply voltage indicated should not be exceeded. Furthermore, it is important that a tube be operated with the proper negative bias (as indicated by the tables) applied to the grid, since failure to do so will not only cause failure of the tube but faulty operation. The amount of grid bias, as pointed out briefly in the preceding article in the case of amplifiers, is largely the determining factor as to the class of amplifier operation obtained.

For the correct use of tubes in circuits it is of course necessary to know how the internal elements are connected to the pins and how the pins are arranged. Tube bases have from four to eight pins for element connections. In all except the five-prong and eight-prong types, the two cathode pins are heavier than the others, making them readily distinguishable and providing an arrangement which permits the insertion of the tube in the socket in only one position. The pins of all tubes except those of the 8-pin or octal base (which is the base developed first for the metal tubes) are numbered in accordance with the system shown in Fig. 166. Looking at the bottom of the base or the bottom of the socket, the left-hand cathode pin is No. 1, and the others are numbered consecutively in a clockwise direction, ending with the right-hand cathode or heater pin.

The metal tubes all have 8-pin bases but only those pins needed for connections are actually molded into the base, consequently a single type of socket will accommodate any tube of the metal series. The development of metal tubes with the octal base system of pin arrangement created a demand for this same type of base arrangement for glass tubes; hence, practically all of the now-used glass tubes can be obtained with octal bases. Such tubes have the suffix "G" attached to the type number. In some cases these tubes duplicate in characteristics types in the metal series; when this is so, the tube carries the same number as the corresponding metal tube but with the suffix "G" added. Thus, the glass equivalent of the 6H6 metal tube is known as the 6H6-G. Other "G" tubes duplicate existing types of glass tubes with old type bases and in still others the tube is a new tube with an octal base. In recent years, a lock type socket has been developed for certain of the octal base tubes. Tubes of this kind have a special type of key and they are known, generally, as "loktal" base tubes.

Many of the tube types found in the tube tables are old tubes which are rarely used today since they have been superseded by better tubes, but these data on these older tubes are necessary for replacement purposes.

In indicating which element is connected to the various pins, it is customary to use the letters, F, F or H, H, for fialment or heater, C or K for cathode, P for plate, etc. In multi-grid tubes the grids are numbered according to the position they occupy, the grid nearest the cathode being No. 1, the next, No. 2, and so on. Some tubes, as may have been noted, are provided with a cap connection on top especially when it is desired that the element connected to the cap have very low capacitance to other tube elements.

The standard method of indicating tube arrangement is shown in Figs. 167 and 168. These diagrams represent views of the bottom of the base or sockets. The disposition of the actual tube elements is shown in the inner circle while the pin arrangement is shown between the inside and the outside circle. The pins are both numbered and lettered. The letters, as explained, denote the elements, F for filament; H, heater; C, cathode; G, grid; S, screen; Sup, suppressor;

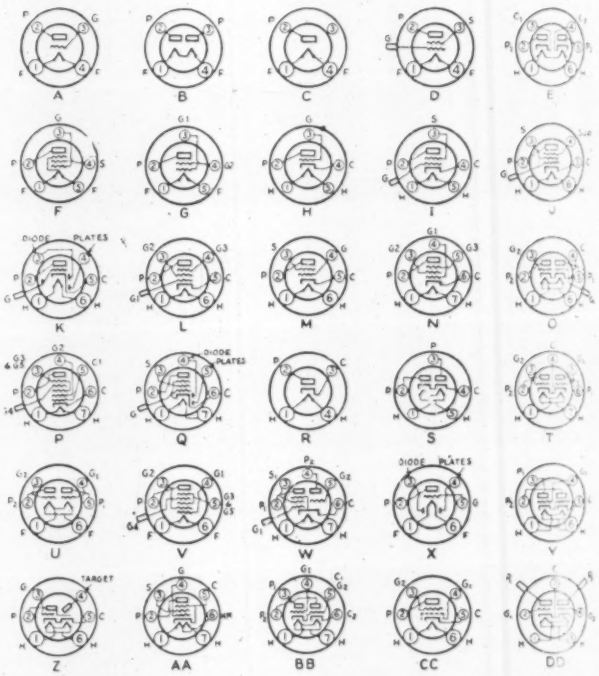


Fig. 167. Base diagrams of glass tubes. These views are of the bottom of the bases or sockets. F, filament; H, heater; C, cathode; G, grid; S, screen: Sup, suppresser; P, plate. G1, G2, etc., denote grids numbered in order from the cathode outward; G_1, G_2, P_1, P_2 etc., denote grids and plates for multi-purpose or twin tubes having separate sets of elements. Elements having the same subscripts belong together. A top cap on the tube is shown by an external unnumbered connection.

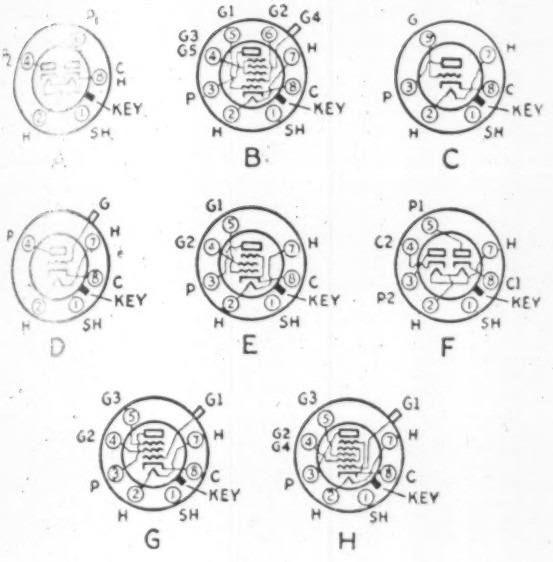


Fig. 168. Base diagrams of metal tubes. Letters and numbers have the same significance as in Fig. 167 but with the addition of DP, diode plates; and SH for shield. The shield is the metal envelope of the tube, in all cases connected to pin No. 1.

P, plate; G1, G2, G3, etc., denote the grids numbered in order from the cathode outward; G_1, G_2, P_1, P_2, etc., denote the grids and plates of multi-purpose or twin element tubes; elements having the same subscripts belong together. A top cap on the tube is shown by an external unnumbered connection.

The letters below each tube diagram refer to corresponding letters in the tube tables, so that the diagram of connections for any tube listed in the tables is easily available. A portion of a tube table is shown in Fig. 169.

In the early days tubes were given arbitrary numbers as they were placed on the market. Now, however, a uniform numbering system is in effect, which, to some extent indicates the nature of the tube. These designations involve a number, a letter, and a final number. An example of this method of numbering is the 2A5. These numbers are formed according to the following simple rules. The first numeral indicates the filament or heater voltage in steps of 1 volt. For instance, 1 is used for voltages below 2.1; 2 is used for voltages between 2.1 and 2.9, inclusive; 3 for voltages between 3.0 and 3.9 inclusive. The digit 1, rather than the digit 2, is used for the 2.0-volt types in order to separate the 2.0 and 2.5-volt tubes.

The letter is used to distinguish the tube type and is assigned, starting with A, in alphabetical sequence. In the case of rectifiers, however, the assignment is made starting with Z, in reverse sequence. The final number indicates the number of useful elements brought out to terminals. Thus the 2A5 has five such elements; a heater, a cathode, two grids and a plate. By this method then, the designation 2A5 means a tube with a 2.5-volt filament voltage with 5 elements brought out to connection and the first 5 element tube of the 2.5-volt series.

The tubes referred to above are those manufactured for general experimental and radio use. For industrial uses special lines of tubes have been developed using different designations and which are said to be more carefully made than the ordinary radio tube, which is not licensed for commercial industrial use. Each manufacturer uses his own method of designating such tubes. Thus, the General Electric Co. will have series of tubes such as PT-841, PT-842, FP-52, KC-1, the prefix usually referring to the type of tube. Westinghouse, on the other hand, will have tubes such as RJ-550, WL-196, KV-676. These industrial type tubes in many cases duplicate the characteristics of the experimental or radio type tubes, but they are usually sold at very much higher prices. The socket arrangements also are usually quite different and the tubes are not interchangeable with those of the experimental type for this reason. Industrial tubes, it must be understood, however, are no different from any other types of tubes, either in principle or size, and the theory of tubes as it has been presented in these articles applies to all. A gas-filled tube going by the name of Phanatron is still a gas-filled tube and if it has two elements it is still a diode. Tubes have been classified by various names such as Kenotrons, Phanatrons, Thyratrons, etc.

This lack of standardization in designating and designing industrial tubes is to be regretted and it arises from no scientific reason; it is primarily the result of commercial and legal factors.

This more or less informal discussion of the commercial forms of tubes is of considerable importance in the practical use of tubes since it may relieve some of the confusion which must inevitably result from the beginner's first encounter with commercial tube data.

In the application of tubes, the tube data tables and the graphic characteristics are of the utmost importance since it is by means of these data that the performance of any

Type	Name	Base [4]	Socket Connections [5]	Cathode	Fil. or Heater Volts	Fil. or Heater Amps	Use	Plate Supply Volts	Grid Bias	Screen Volts	Screen Current Ma.	Plate Current Ma.	Plate Resistance, Ohms	Mutual Conductance Micromhos	Amp. Factor	Load Resistance Ohms	Power Output Watts	Type
6A4 [1]	Pentode Power Amplifier	5-pin M.	F	Fil.	6.3	0.3	Class-A Amplifier	100 180	−6.5 −12.0	100 180	1.6 3.9	9.0 22.0	83250 45500	1200 2200	100 100	11000 8000	0.31 1.40	6A4
6A6	Twin Triode Amplifier	7-pin M.	T	Htr.	6.3	0.8	Class-B Amplifier	250 300	0 0	—	—	Power output is for one tube at stated load, plate-to-plate				8000 10000	8.0 10.0	6A6
6A7	Pentagrid Converter	7-pin S.	P	Htr.	6.3	0.3	Converter	250	−3.0 min.	100	2.2	3.5	360000	Anode grid (No. 2) 4.0 ma. Grid leak, 50000 ohms		200 volts max.		6A7
6B5	Special Power Amplifier	6-pin M.	Y	Htr.	6.3	0.8	Class-A Amplifier	300	0		6 [3]	45	24100	2400	58	7000	4.0	6B5
							Push-Pull Amplifier	400	−13		4.5 [3]	40	—	—	—	10000	20	
6B7	Duplex-Diode Pentode	7-pin S.	Q	Htr.	6.3	0.3	Pentode R.F. Amplifier	250	−3.0	125	2.3	9.0	650000	1125	730	—	—	6B7
							Pentode A.F. Amplifier	250	−4.5	50	—	0.65	—	—	—	—	—	
6C6	Triple-Grid Detector Amplifier	6-pin S.	J	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	250	−3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	—	—	6C6
							Bias Detector	250	−1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms				
6D6	Triple-Grid Variable-μ Amplifier	6-pin S.	J	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	250	−3.0	100	2.0	8.2	800000	1600	1280	—	—	6D6
							Mixer	250	−10.0	100	—	—	—	Oscillator peak volts = 7.0				
6E5	Electron Ray Tube	6-pin S.	Z	Htr.	6.3	0.3	Indicator Tube	200 250	0 0	— —	— —	0.2 0.25	Target Current 4.0 ma. Target Current 4.5 ma.				—	6E5
6F7	Triode Pentode	7-pin S.	W	Htr.	6.3	0.3	Triode Unit Amplifier	100	−3.0	—	—	3.5	17800	450	8	—	—	6F7
							Pentode Unit Amplifier	250	−3.0	100	1.5	6.5	850000	1100	900	—	—	
							Pentode Unit Mixer	250	−10.0	100	0.6	2.8	Oscillator peak volts = 7.0				—	
36	Tetrode R.F. Amplifier	5-pin S.	I	Htr.	6.3	0.3	Screen-Grid R.F. Amplifier	100 180 250	−1.5 −3.0 −3.0	55 90 90	— — 1.7	1.8 3.1 3.2	550000 500000 550000	850 1050 1080	470 525 595	—	—	36
							Bias Detector	100 250	−5.0 −8.0	55 90	—	Plate Current to be adjusted to 0.1 ma. with no signal					—	
37	Triode Detector Amplifier	5-pin S.	H	Htr.	6.3	0.3	Class-A Amplifier	90 180 250	−6.0 −13.5 −18.0	— — —	— — —	2.5 4.3 7.5	11500 10200 8400	800 900 1100	9.2 9.2 9.2	—	—	37
							Bias Detector	90 250	−10.0 −28.0	—	—	Plate Current to be adjusted to 0.2 ma. with no signal					—	

Fig. 169. A portion of a typical tube table.

tube can be predetermined. It is essential, therefore, that one should become at least reasonably familiar with the different types of tubes on the market and with the meaning of the data presented in the tables.

In considering the characteristics of electron tubes, it may be pointed out that these fall into two classes, the first known as the static characteristics and the second the dynamic characteristics. The static characteristics are values of certain properties of the tube obtained with different d-c. potentials applied to the tube electrodes, while dynamic characteristics are the values obtained with an a-c. voltage on the control grid under various conditions of d-c. potentials on the electrodes. The dynamic characteristics are, therefore, indicative of the performance capabilities of a tube under actual working conditions. Dynamic characteristics include amplification factor, plate resistance and mutual conductance.

The amplification factor of a tube or the μ is the ratio of the change in plate voltage to a change in control-electrode voltage in the opposite direction under the condition that the plate current remains unchanged. For example, if the plate voltage is changed 30 volts and the grid voltage is changed 5 volts (in opposite polarity) in order to hold the plate current at a constant value, the amplification factor is 30 divided by 5, i.e., 6. In other words, a small voltage variation in the grid circuit of a tube has the same effect on the plate current as a large plate voltage change—the latter equal to the product of the grid voltage change and the amplification factor.

The plate resistance of a tube is the resistance of the path between cathode and plate to the flow of alternating current. It is the ratio of a small change in plate voltage to the corresponding change in plate current, and is expressed in ohms. Thus if a change of 0.001 amp. is produced by a plate voltage variation of 10 volts the plate resistance is 20 divided by 0.001 or 20,000 ohms.

The mutual conductance or, as it is sometimes known, the grid-plate transconductance, is a factor which combines in one term the amplification factor and the plate resistance; it is the ratio of the first to the second. Mutual conductance may be more strictly defined as the ratio of a small change in plate current to the small change in the control-grid voltage producing it, under the condition that all other voltages remain unchanged.

Thus, if a grid voltage change of 10 volts causes a plate current change of 0.01 ampere (10 ma.) with all other voltages constant, the mutual conductance is 0.01 divided by 10 or 0.001 mho. Since the plate current changes involved are usually very small, the mutual conductance is usually expressed in millionths of a mho, or micromhos. Therefore, in the example, 0.001 mho times a million equal 1000 micromhos. The mutual conductance characteristic of a tube is a very useful one when comparing a tube's performance capabilities with those of the same type in similar applications.

XXV. AMPLIFIER CLASSIFICATIONS

The first important application of the electron tube and still perhaps its most universal application was that as an amplifier—an amplifier of the extremely weak but complex electric currents used in the transmission of speech over telephone systems. This was its first major general application and as described in an earlier article it resulted in benefits to mankind which can scarcely be measured in terms which we usually associate with value. Overnight, almost, it revolutionized the art of telephony, extending the limits of voice transmission to the farthest reaches of the earth; it made round-the-world telephony an actuality. Since that time when it was first impressed in service as a "repeater" by the telephone engineers, the electron tube has been applied as amplifiers of electric currents and impulses in countless other services and though the requirements in these services vary widely, still the principles involved in all these applications are essentially the same. There are differences, however, and these should be understood.

Several amplifier applications and the princi[ples] involved have already been described but the correct use of amplifiers requires a more detailed knowledge of the way tubes work and how they can be used to fulfill certain requirements. This is particularly true in the field of instrumentation where the output of a device not only has to be amplified but must be an exact reproduction of whatever variable it is necessary to measure. This is not as simple as it sounds.

If a sensitive millivoltmeter is connected across a low resistance shunt carrying current, we know that the voltmeter, assuming it to be properly calibrated, will measure the electromotive force developed across the terminals of the shunt.

Suppose, however, that the voltage variations are so minute that they cannot be measured by the voltmeter. This, it would seem, provides an excellent opportunity to use electronics; why not interpose an electron-tube amplifier between the shunt and the millivoltmeter? The amplifier will amplify the minute voltages appearing across the shunt and the amplified voltage can then be measured by the voltmeter.

In theory this is fine and, practically, it can be accomplished but only if extreme care is taken. To accomplish it

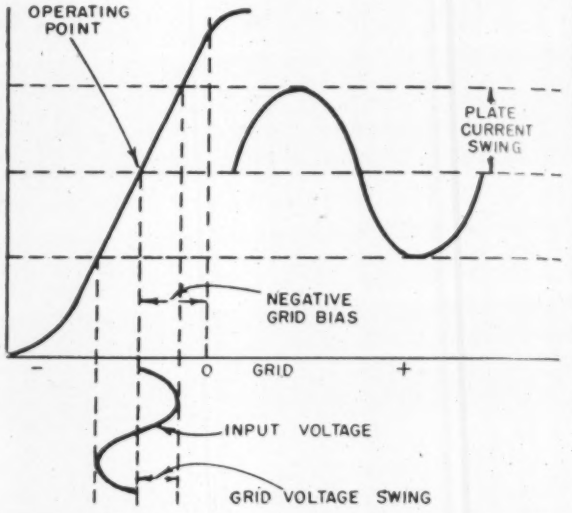


Fig. 170. The operating characteristics of an electron tube amplifier. This diagram represents the action of a Class A Amplifier. Plate current flows all the time whether the grid is excited or not.

the amplifier must be absolutely stable, and this is not an easy thing to achieve. It is easier now than it was a decade or so ago because of the development of the principle of "feedback" but considerable care is still necessary. Feedback will be discussed later.

Of course, amplifier requirements vary widely. Sometimes, as in "counting" operations, all that is required is the amplification of single or multiple impulses in which case the electron tube functions primarily as a relay. At other times the output of the amplifier must reproduce faithfully, without distortion, the shape of an alternating current wave applied to the input. Sometimes mere amplification of potential is desired; at other times actual amplification of power is necessary.

In many industrial applications where the electron tube is used primarily as a relay, only the simplest principles apply but in the field of instrumentation where the amplified current or voltage must in most cases be an accurate amplified reproduction of the input current, a more intimate knowledge of tube characteristics is necessary.

As pointed out in some of the preceding articles, the manner in which an amplifier tube is operated to fulfill certain conditions depends largely upon the way the grid is biased, that is, upon the value of steady negative potential applied to the grid. This principle of changing a triode's operating conditions by varying the negative potential of the grid was discussed in some detail in the July '43 article. It may be recalled that the operation of an electron tube

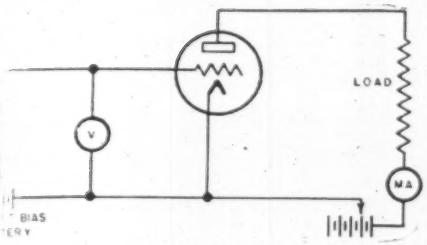


Fig. [illegible] The elements of an amplifier circuit, showing the use of a grid bias battery for adjusting the negative potential of the grid.

as an amplifier can be represented graphically, by plotting the plate current at right angles to the grid potential in the manner shown in Fig. 170. This diagram makes use of the plate-current vs. grid-voltage characteristics. With any given value or type of grid input voltage, such a curve will show the character of the current which will flow in the plate circuit under certain conditions of plate voltage.

If the grid of an amplifier tube is biased properly negative, so that the peak input voltage as shown by Fig. 170 will not cause the grid potential to become positive at any point in the cycle or cause the plate current to traverse the lower curved part of the characteristic on the negative half-cycle, the output wave will be an exact but amplified reproduction of the input wave. Under these conditions the amplification will be distortionless.

It will be noted that the input voltage oscillates about an axis which is displaced negatively from the zero bias point. This displacement represents the "grid bias," that is, the fixed negative potential of the grid with respect to the cathode. Assuming that an alternating potential is to be amplified, the instantaneous values of the alternating potential with respect to the cathode can be varied relative to zero by means of a grid bias potential obtained from a battery or other source, as shown in Fig. 171.

By increasing the negative potential of the grid, the axis of the grid input voltage wave in Fig. 170 is shifted to the left; by decreasing it or making it positive with respect to the cathode, the axis is shifted to the right. The cathode, it must be remembered, is always considered the zero potential reference point; the biasing battery is always connected between the grid and the cathode. In either case, when the amount of the shift is such that critical values are reached (where the projection of the grid voltage values intercept the lower or upper curved portions of the characteristic) the shape and character of the plate current curve is altered, i.e., it becomes distorted and is no longer an accurate amplified reproduction of the grid voltage curve.

Cut-off Point

It will be evident from Fig. 170 that if the negative grid bias is increased a sufficient amount, the plate current may be stopped entirely. This is known as the cut-off point. The cut-off point of an amplifying tube is the amount of grid bias voltage needed to stop completely the electron flow from cathode to anode.

The significance of "bias voltage" and "cut-off point" can be better understood with the aid of the curve shown in Fig. 172. It shows how the plate current, measured vertically, varies in relationship with applied bias voltage. On this particular curve, for example, at 20 volts negative bias, the plate current is approximately zero. In other words, 20 volts negative bias corresponds to the tube's cut-off point. This term cut-off point is one that is used frequently in discussions of various classes of amplifiers.

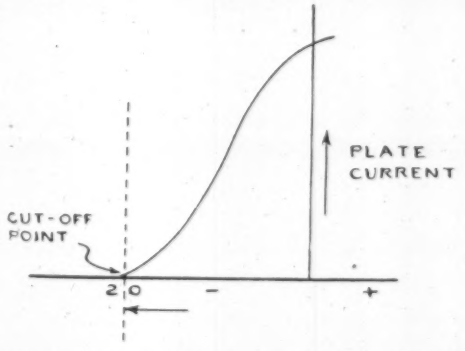


Fig. 172. Curve showing the "cut off" point. At −20 volts, the plate current is approximately zero.

An amplifier operated in the manner shown in Fig. 170 in which the output wave shape is a faithful reproduction of the input wave shape, is known as a *Class A* amplifier. It is one of the three fundamental types of amplifiers, the other two being designated as *Class B* and *Class C*.

The classification of amplifiers depends primarily on the fraction of the input cycle during which plate current is expected to flow under rated full-load conditions. A *Class A* amplifier is an amplifier in which the bias voltage is located about midway between the cut-off point and zero. The grid bias and the exciting grid voltage are such that plate current flows through the tube all the time. Even with no input there is a steady normal plate current, the value depending upon the grid bias. Because of this, the fact that plate current flows in the absence of an exciting voltage, the plate efficiency* is relatively low, being in the neighborhood of 20 to 35 percent at full output. The plate efficiency cannot be greater than 50 per cent, since the

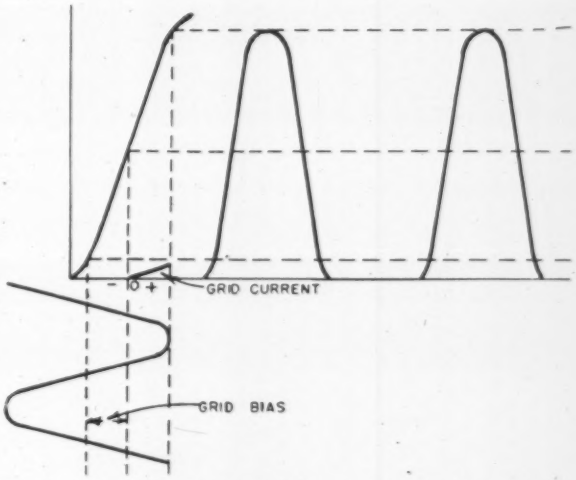


Fig. 173. Class B Amplifier operation. This graph shows Class B action. The grid bias is adjusted so that when no exciting potential is applied, the plate current is zero or very nearly zero.

normal plate current must be such as to permit the full amplitude of the negative half of the cycle without at any time reaching zero. The chief characteristics of the Class A amplifier are low distortion, low power output for a given size tube and a high power-amplification ratio.

Leaving the Class A type of amplifier for the moment, let us consider the *Class B* type. The Class B amplifier is one in which the grid bias is approximately equal to that required to cut off the plate current to approximately zero when no exciting grid voltage is applied. This method of operation is shown in Fig. 173. It will be noted that the grid bias is of such a value as to bring the plate current practically to zero with no excitation (no input voltage). As a consequence no plate current flows during the negative half of the exciting voltage. Since practically only the linear portion of the characteristic is used, the plate current pulses are of essentially the same shape as that of the positive half of the input cycle. As in the case shown, since the plate current is driven upward toward the saturation point, it is usually necessary for the grid to be driven positive with respect to the cathode during part of the grid "swing." Grid current flows, therefore, and the driving source must be capable of furnishing power to supply the grid losses.

Since no plate current flows during a considerable portion of the cycle it will be obvious that the Class B amplifier

*The ratio of a-c. output power to steady d-c. input.

has a higher plate efficiency than the Class A. The Class B amplifier is characterized by medium power output, medium plate efficiency (50 to 60 percent) and a moderate ratio of power amplification.

In Class B operation, it will be evident that even though the plate current pulses are of the same shape as the positive grid swing, such an arrangement will not give an exact reproduction of the input wave, since only half-cycles are present in the output. For this reason, to obtain distortionless amplification with tubes used as Class B amplifiers, it is necessary to use two tubes working alternately so that both halves of the cycle will be present in the plate circuit. Such an arrangement is shown in Fig. 174. The input current is fed to a transformer T_1 whose secondary is divided into two equal parts, with the tube grids connected to the outer terminals and the grid bias fed in at the center. Another transformer, T_2, with a similarly divided primary, is connected to the plates of the tubes, the plate voltage being fed in at the center tap. When the input swing in the upper half of T_1 is positive, tube 1 draws plate current while tube 2 is idle; when the lower half of T_1 becomes positive, tube 2 draws plate current while tube 1 is idle. The corresponding voltages produced in the halves of the

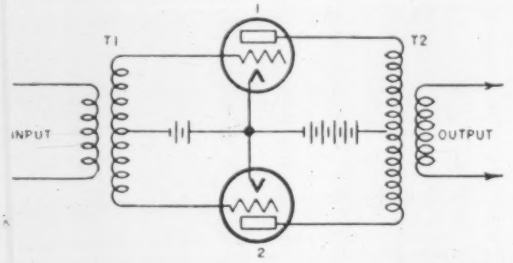


Fig. 174. Circuit using two tubes in "push-pull" to provide distortionless amplifications with tubes used as Class B Amplifier.

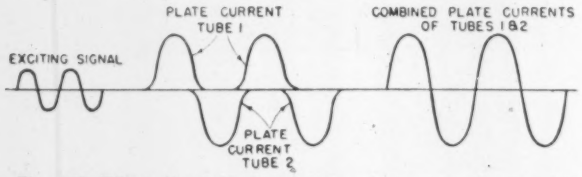


Fig. 175. Wave diagrams showing how the output of two tubes in Class B are combined to give distortionless amplifications in a push-pull circuit.*

primary of T_2 combine in the secondary to produce an amplified reproduction of the input wave shape with practically no distortion. The way in which these secondary currents combine is shown in Fig. 175. *A circuit using two tubes in this manner is ordinarily known as a "push-pull" arrangement;* it can be used with other classes of amplifiers as well as for Class B, but in the case of the latter, for distortionless amplification it becomes a necessity.

As will be evident from Fig. 173, by designing tubes with a sufficiently high amplification factor it is possible to operate them in Class B with zero grid bias and so dispense with all bias batteries or bias resistors.* It is for this reason that such specially-designed tubes are better for Class B amplifiers than tubes not specially designed for that purpose.

Now we shall consider the third general class of amplifiers, i.e., *Class C.* In a Class C amplifier, the grid is biased

*The negative potential for the grid can also be supplied from a resistor (usually called a grid leak) connected between the grid and the cathode. In this case the negative potential is a function of the grid current, the voltage representing the voltage drop produced by the grid current across this resistor. The grid potential thus is obtained by multiplying the grid current in amperes (milliamperes ÷ 1000) by the resistance in ohms. This method of securing a grid bias potential, while effective, has the disadvantage that should the excitation fail for any reason, with full plate voltage on the tube the grid bias would be lost and the plate current might rise to destructive values. In many instances, therefore, a combination of the two methods is used, a battery being connected in series with the resistance. Just enough battery voltage is used to keep the plate current at a safe value without excitation and the remainder is supplied by the drop across the resistor.

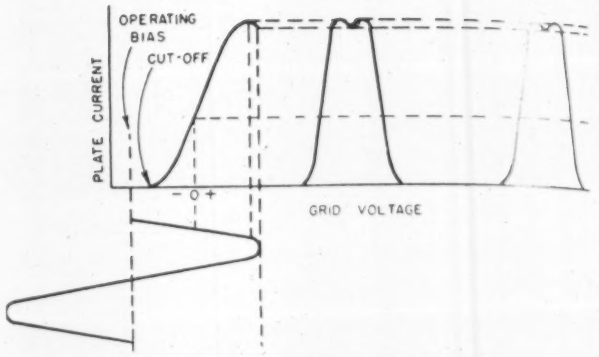


Fig. 176. Class C Amplifier operation. With Class C, the grid bias is adjusted so far below the point of cut-off that plate current flows for only a fraction of the positive excitation cycle.

appreciably beyond the cut-off value so that the plate current flows from appreciably less than one-half of each cycle when an exciting grid voltage is present. The grid bias for such an amplifier is usually set at approximately twice the value required for plate current to cut off without excitation. The exciting voltage should be of sufficient amplitude to drive the plate current to the saturation point as shown in Fig. 176 which shows the principle of Class C operation. Since the grid must be driven far into the positive region to cause saturation, a considerable number of electrons are attracted to the grid at the peak of the cycle, robbing the plate of some that it would normally attract.* This causes the droop at the upper bend of the characteristic and causes the plate pulse to be indented as shown. This type of amplifier operation is used exclusively for radio-frequency power amplifiers. The output wave-form is badly distorted but at radio frequencies this distortion is largely eliminated by the filtering or flywheel effect of the tuned output circuit.

As a matter of fact, for radio-frequency amplifiers which operate into selective tuned circuits or under requirements where distortion is not an important factor, any of the foregoing classes of amplifiers may be used either with a single tube or with a push-pull stage. For audio frequency amplifiers in which distortion is a controlling factor, only the Class A amplifier permits single-tube operation.

For many industrial applications distortion is of little import. In many instances the only thing desired is the greatest change in plate current with a given grid voltage excitation. What is important is not the magnitude of the current but the magnitude of the change in current. For this reason most industrial amplifiers are biased so that the plate current without excitation is small or zero.

These methods of using amplifiers as Class A, B, or C do not affect other considerations of amplifiers discussed in preceding articles. The question of neutralizing, for example, is exactly the same in each case and just as necessary. So also is the matter of coupling one circuit to another. A few additional remarks about coupling, however, will not be out of place.

We have shown how the output of one amplifier may be fed into a succeeding one by means of a transformer, T_2, whose secondary is connected in the grid-cathode path of the second tube, as in Fig. 177. In this case the transformer is usually a step-up transformer, the ratio adjusted to obtain a high amplification. If amplification over a compara-

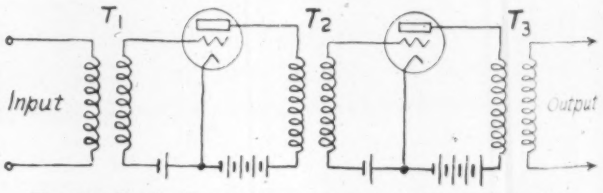


Fig. 177. Circuit diagram showing the use of interstage transformers for coupling the output of one amplifier to the input of another.

*At saturation, all of the electrons emitted by the cathode are attracted to the plate and no further increase in plate voltage will bring about a further increase in plate current. If, under these conditions, the grid begins to attract some of the electrons there will be just that many fewer reaching the plate.

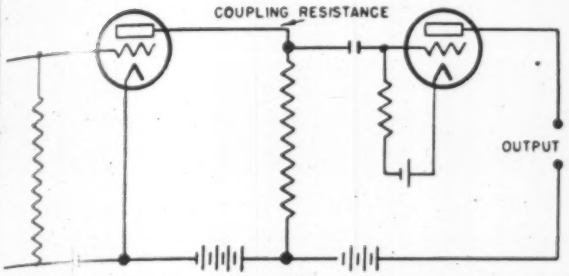


Fig. 178. Another multistage amplifier, similar to that shown in Fig. 177 but using a coupling resistance instead of a transformer.

tively narrow range of frequencies is desired, say only at 60 or 100 cycles, the ratio of turns between the primary and secondary may be high: 10 to 1 or more, but where a wide band of frequencies must be amplified, such as in an amplifier for music or voice currents, as in a radio receiver, only a small transformer ratio can be used. This is due to the fact that it is extremely difficult to make transformers which will transform a wide range of frequencies with equal efficiency.

Where a wide band of frequencies is to be amplified, *resistance coupling* can be used. In this case a high resistance is connected in the plate circuit, as shown in Fig. 178. The plate current flowing through the coupling resistance results in a voltage drop across it and it is this voltage drop that is impressed on the grid of the next tube through a small capacitor. This capacitor is necessary in order to prevent the plate voltage on the first tube from being impressed on the grid of the second tube.

A third method of coupling is known as *impedance coupling*. This is similar to the resistance method except that a choke coil or high impedance forms the coupling element. The action is very much the same as with resistance coupling, the voltage developed across the impedance being applied to the next tube. The impedance coupling method permits the use of lower plate voltages than with resistance coupling.

Power Amplifiers

One thing more regarding amplifiers, and that concerns the question of voltage or power amplification. Amplifiers may be divided broadly into two general types, first, those which provide a greatly magnified reproduction of the input wave without regard to the power delivered and, second, those which are designed to deliver a relatively large amount of power to a load. In the first case, the amplifier is known as a voltage amplifier, while in the second it is a power amplifier.

In the case of a power amplifier, a large grid voltage swing is necessary for full power output. To obtain this large grid voltage swing for the grid of such a tube it is necessary to use voltage amplifiers which greatly increase the amplitude of the impulse to be amplified as amplifiers ahead of the "power" stage. In general, the last stage of any amplifier is a power amplifier, since it is usually necessary to operate some device or circuit requiring power.

A final word regarding the plate voltage of an amplifier. In the diagrams shown in this article, it will be noted that only the grid voltages and the plate *currents* were shown. The plate voltage was not shown. To prevent any misunderstanding concerning the plate voltage, Fig. 179 may be of interest. Here it will be noted both the plate current and the plate voltage are shown but note that the plate voltage is 180° out of phase with the plate current. This is always true.

In Fig. 179 the circuit diagram is shown at the lower right of the operating characteristics. As the signal voltage swings between −2.5 volts and −7.5 volts the plate current swings between 3.5 ma. and 1.5 ma. The maximum plate current, 3.5 ma. occurs at the instant the grid voltage is −2.5 volts. Similarly, the minimum plate current, 1.5 ma. occurs at the instant the grid voltage is −7.5 volts. At intermediate values of grid voltage, intermediate plate-current values will occur. Thus it is seen that the plate current is in phase with the grid voltage.

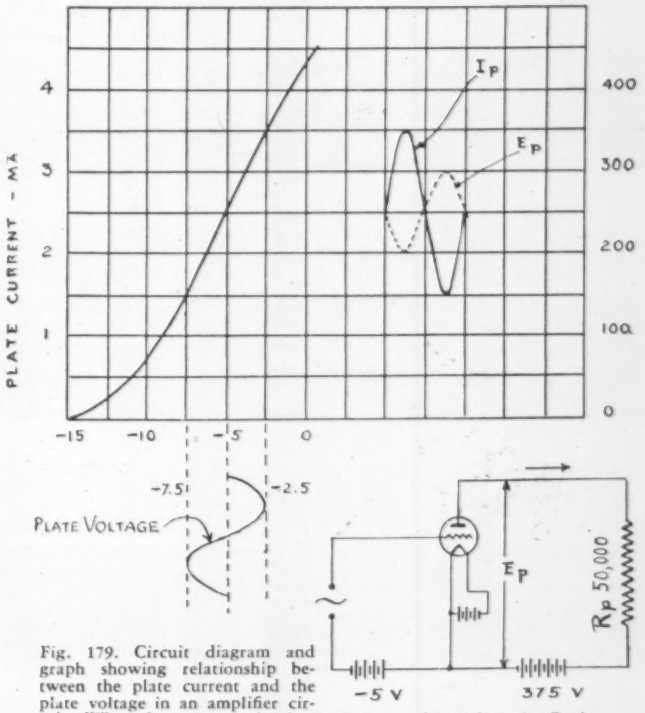


Fig. 179. Circuit diagram and graph showing relationship between the plate current and the plate voltage in an amplifier circuit. When I_p = max. the instantaneous voltage drop in R_p is 50,000 × 0.0035 = 175 volts. When I_p = min., the instantaneous voltage drop in R_p is 50,000 × 0.0015 = 75 volts.

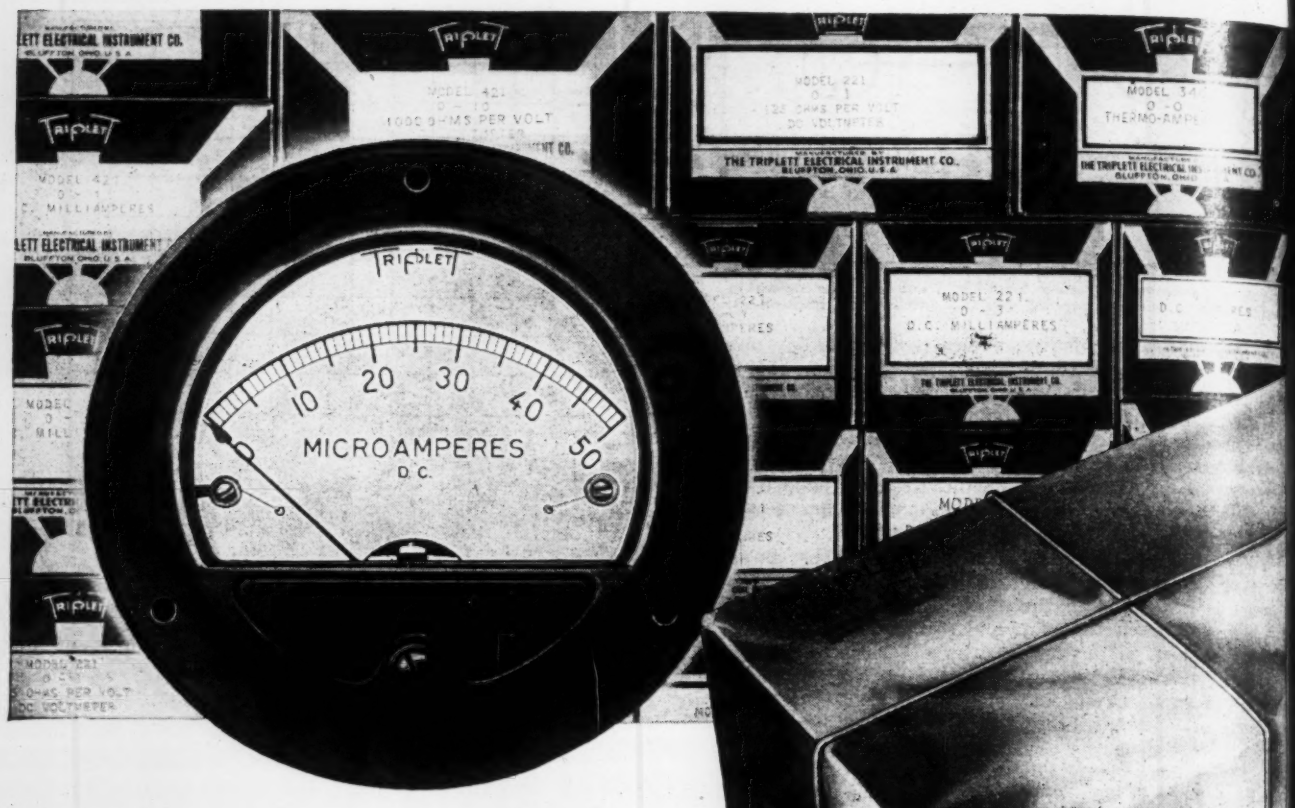
The instantaneous voltage between the plate and the cathode of the tube is shown by the dotted curve *Ep*. When the plate current is maximum the instantaneous voltage drop in *Rp* is 50,000 × 0.0035 = 175 volts. In the same way, when the plate current is minimum, the voltage drop in *Rp* is 50,000 × 0.0015 = 75 volts. The actual voltage between the cathode and plate is therefore the difference between the plate supply voltage, 375 volts, and these voltage drops in the load resistance, or 200 volts (375−175) and 300 volts (375−75) respectively.

The varying plate voltage is an a-c. voltage superimposed on the steady plate-cathode voltage of 250 volts which is the voltage established for no signal conditions. The peeak value of this a-c. output voltage is the difference between either the maximum or minimum plate-cathode voltage and the no signal value of 250 volts. This difference, in the example under consideration is 300−250 or 250−200 or 50 volts. Since the grid signal voltage has a peak value of 2.5 volts the voltage amplification ratio of the amplifier is 50 ÷ 2.5 = 20. In other words, 20 times as much voltage is obtained from the plate circuit as is applied to the grid circuit.

XXVI. ELECTRONICS IN THE FIELD OF MEASUREMENT

In no field does the electron tube lend itself to a greater variety of applications than it does in the field of measurement—the field of instrumentation. Whether it be in the measurement of length or of mass, of time or of physical magnitudes such as temperature or viscosity, or of electrical magnitudes, or of radiation, no matter how refined the previous or existing methods, the application of electronics has been able to effect improvement in practically every instance. This is especially true in relation to the everyday types of measurement necessary in high-speed industrial production. Today, factory workers make routine measurements with a degree of precision that a few decades ago was possible only in a laboratory when performed by highly-skilled technicians. Because of electronics, every branch of mechanical, chemical and electrical measurement has been vitalized and carried to almost incredible precision and facility. In the field of microscopy, for example, the electron microscope has made possible the measurement of

Continued on page 618



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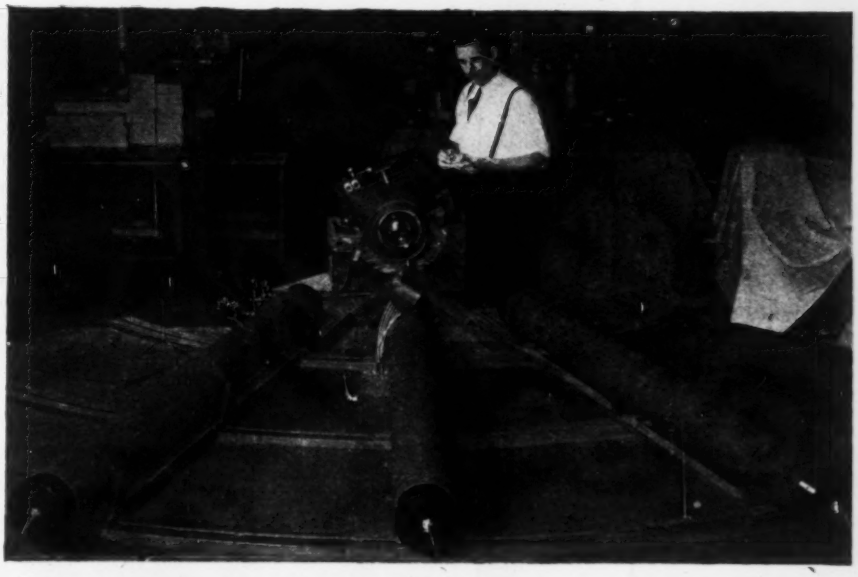
Vol. III, No. 10 M. F. Behar, Editor October 1944

For Accuracy in Aerial Photography

IN the two adjoining photographs are shown for the first time, by permission of the Army and Navy and by courtesy of the manufacturers, details of a device which has contributed to the precision aerial photography of our Air Forces. In appearance it is triple-tube fan-shaped instrument. It is an improved lens collimator, especially designed by engineers of Fairchild Camera & Instrument Corporation for final testing of Fairchild aerial camera lenses, *after* installation in the cameras. Its purpose is to give a photographic record of the resolving power of each lens, for correct focusing.

A Fairchild Model K-18 camera, used by both the Army and Navy in military intelligence photography from the air, is shown mounted for testing. It contains a lens of 24-inch focal length. The two outer collimator tubes, each including a lens and an illuminated chart



showing perpendicular reticle lines, swing out to cover the edge of the field of the lens (a matter that has often been neglected in ordinary focusing tests). The middle collimator tube, similarly equipped, covers the center of the field. The entire collimator, focused at infinity, transmits parallel rays of light to the camera lens for photographing on a test negative.

Simultaneously, a small recording collimator, set atop the middle collimator, records the serial number of the lens on the film. By means of this accumulated information on the negative, the operator can determine the sharpness of detail covering the entire angle of view, can also determine any possible error from zero, and gage the length of any such error.

This instrument is installed in the Fairchild camera plant at Jamaica, N. Y.

IN *his radio show, Dunninger read in Henry Kaiser's mind that "the helicopter of the future will have only one instrument." . . . Any bets?*

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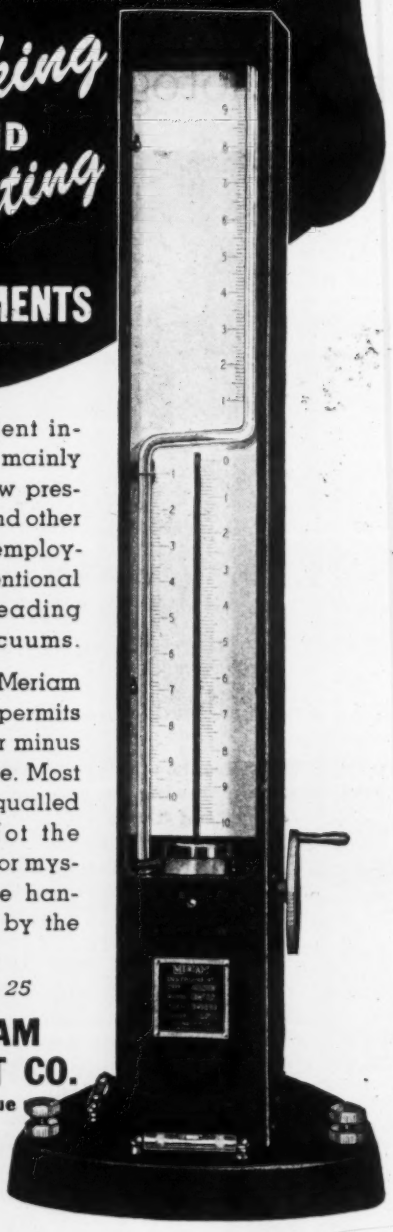

• This new, efficient instrument is used mainly for calibrating low pressure instruments and other devices. It can be employed also as a conventional manometer for reading pressures or vacuums.

Highly sensitive, the Meriam Micromanometer permits readings to plus or minus .001" water pressure. Most rugged, and unequalled in simplicity. Not the least complicated or mysterious, it can be handled successfully by the average operator.

Ask for Bulletin 25

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Finger-tip Control for Man-made Hurricane

PREPARATIONS for investigations of full-size airplanes under simulated flight conditions are complete at the new wind tunnel built and operated by the National Advisory Committee for Aeronautics in Ames Aeronautical Laboratory, Moffet Field, Calif. Engineers are at the end of a war vital job that has taken more than three years: building a full-scale wind tunnel larger than any other in the world—dwarfing even the N.A.C.A. full-scale wind tunnel at Langley Field, Va., previously the world's largest.

Assisting the Ames engineers and also working on night-and-day schedules are engineers for the Westinghouse Elec. & Mfg. Co., who helped install and test the six giant electric motors and other allied apparatus which powers and controls the "hurricane".

Everything about the new tunnel is big. The test section is 80 ft. wide and 40 ft. high. This will enable the testing not only of full-size planes including some of the two-engine types, but also extraordinarily large models of the largest planes. Each of the 6,000 hp. motors weighs approximately 114,000 lbs. and measures 21 ft. long by 10½ ft. in diameter. Each motor will drive a six-bladed spruce propeller 40 ft. in diameter, at any desired speed from 50 to 25[illegible] r.p.m. The six motors will consume a total of about 30 million watts—power enough for 30,000 average homes.

Despite size and bulk of the installation, starting or stopping the battery of six motors can be accomplished by pressing a button. Control of the huge motors presented Westinghouse and Ames engineers with problems seldom met on as large a scale. Solution was found in what is known as the modified Kraemer control system. This system, an arrangement of electrical motors and generators with associated automatic-control devies, will serve to start the fan motors and get them up to the desired speed with minimum disturbance to the power line; will enable smooth, synchronized operation of the six motors over a wide range of speeds, and will convert a large percentage of potential power losses into available energy. Control-system motor-generator sets are even larger and heavier than the motors. One set is 39 ft. long, 11 ft. high and weighs 405,000 lbs.

Some Calibration Short-cuts

By H. C. HACKLEY, Ass't Foreman, A&R Instrument Shop, N.A.S. Moffet Field, Calif.

FOR the beginner in Aircraft Instrument work, calibration often sets up many difficult problems. The following instructions have been found to be of help to our new employees:

The beginner should remember that there are three fundamental conditions that require calibrating in aircraft instruments: (1) Zero adjustment; (2) Range adjustment; (3) "Curve" adjustment.

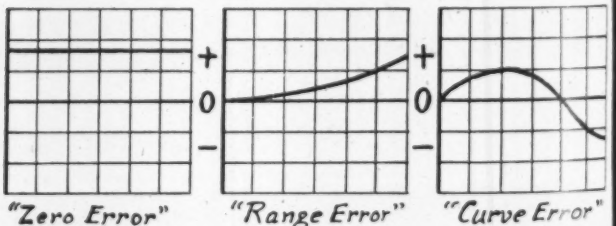

Fig. 1

These conditions for individual instruments are easiest to recognize when a calibration run is plotted on graph paper. To illustrate the above-mentioned conditions the three sketches shown in Fig. 1 are given.

These three sketches show the general appearance of each condition existing by itself. However, various combi-

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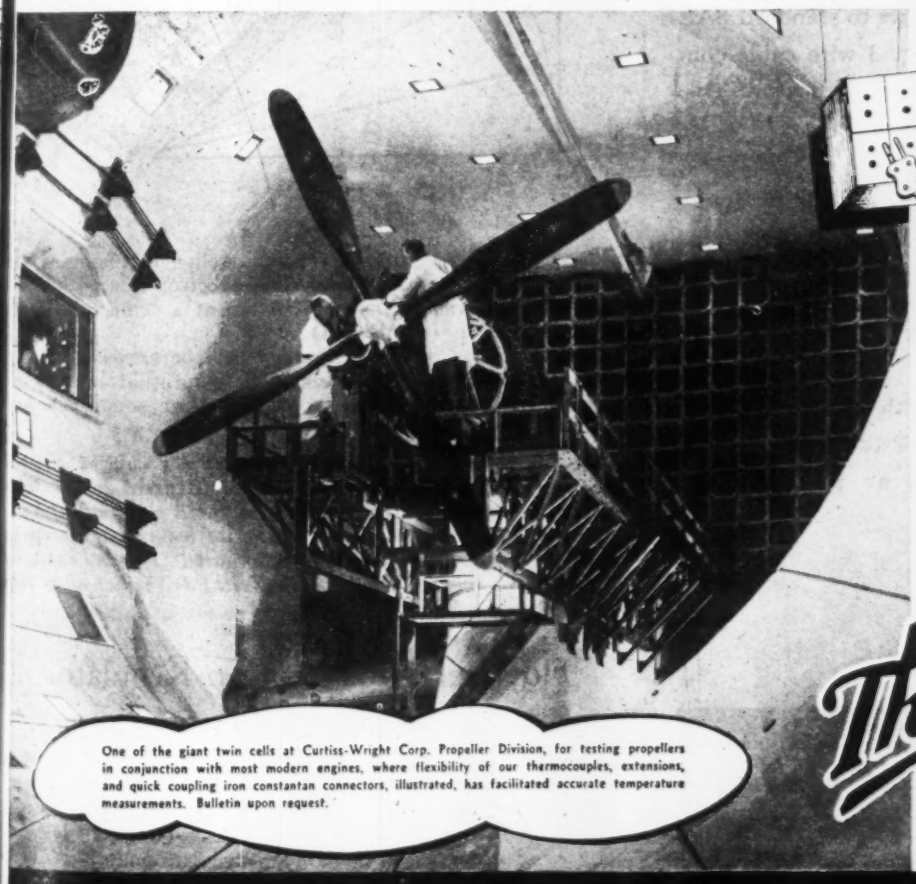

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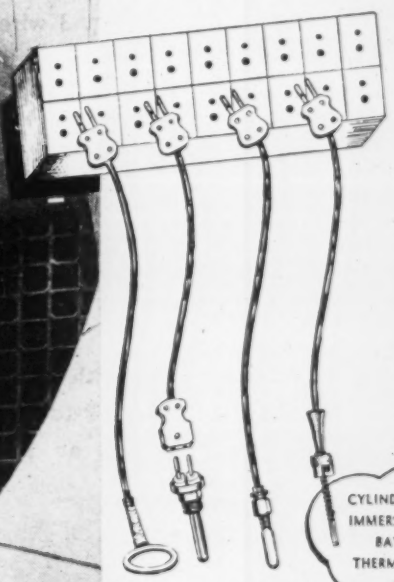

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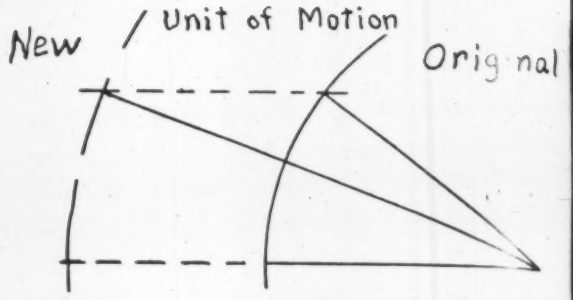


Fig. 2

nations of any two, or of all three, of these conditions are often found in instruments received in a repair shop.

Zero adjustment in most cases is controlled by putting the pointer on zero to start with, after making sure that all mechanical stops are not interfering with the movement of the mechanism.

Range adjustment is usually controlled by the following methods in pressure instruments. The length of a radius arm may be varied: (a) Lengthening a radius arm: A unit of motion applied on the outer extremity of the arm will cause less angular movement on any point connected to the arm (see Fig. 2). (b) Shortening a radius arm produces the opposite effect; it speeds up movement on the driven side per unit of motion of arm.

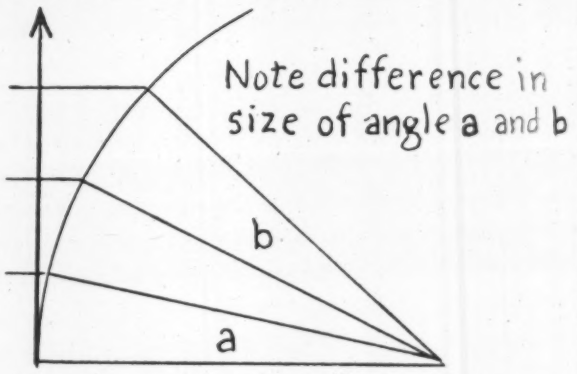


Fig. 3

Curve characteristics may be controlled by changing the portion of the arc being used. The effect of this is to speed up pointer movement on one portion of a scale relative to another portion (see Fig. 3).

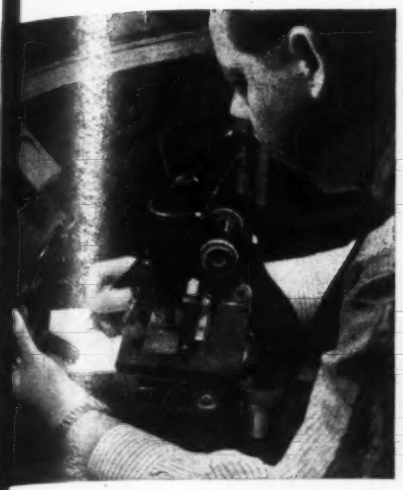
Initial *tension* of the *hairspring* may be varied.

In actual practice it is usually found that making an adjustment on range will affect the curve somewhat, and vice versa.

EDITOR'S NOTE—*This important subject can be treated briefly (as Mr. Hackley has done) or at great length with mathematical proofs (as is done in texts on kinematic design, etc.) In our October 1942 issue we ran a two-page article "Calibrating Pressure-actuated Instruments by Means of Graphs," by Ellsworth Keith, Jr., which goes into more details.—MFB*

Flowmeter for Oxygen Regulator Test Sets

SAFETY of aviators flying above 20,000 feet depends upon proper functioning of aircraft oxygen regulators. This can only be ensured by periodic checking with special testing equipment. At the request of the Bureau of Aeronautics of the Navy Department, the National Bureau of Standards has developed a readily portable field test set so that this necessary checking can be carried out at any landing field. With the great increase in the number of planes



Spencer Microscope and "Bright-line" Counting Chamber in use in the laboratory of the Caterpillar Tractor Co. of Peoria, Illinois.

HEALTH on the Home Front

Dust is one of the greatest hazards to the health of industrial personnel.

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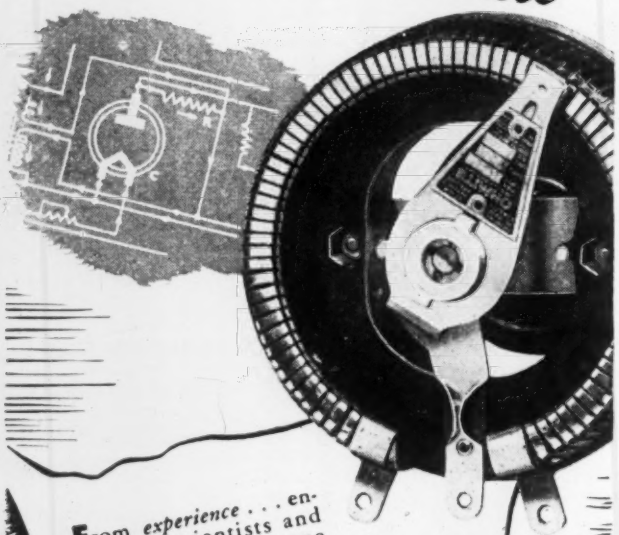

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in service there has been an urgent demand from both the Army and the Navy for these sets.

Accurate flowmeters to measure the rate of flow of oxygen, or oxygen and air mixtures, are essential parts of each unit. Originally, a commercial "rotameter" was used, but the demand for rotameters for other essential uses might have delayed deliveries of the sets. Development work was therefore, rushed on a flowmeter of a new type that could be manufactured easily and quickly from noncritical materials, and which has proved to be even better for the purpose than the rotameters previously used. This "National Bureau of Standards Flowmeter" is simply a can of tightly packed glass wool through which the oxygen or air flows. The pressure difference between the ends o fthe can, measured by a differential pressure gage, is directly proportional to the flow. The final designs of this flowmeter were furnished to the manufacturer, and the field test sets in which it is included are being calibrated at the Bureau as rapidly as they are produced.

ELECTRON TUBE PRINCIPLES

(Continued from page 611)

dimensions too small to be amenable to perception by light waves.

Measurement has been said to be the basis of all science. This being true, electronics has been of inestimable value in extending the field of research by making it possible to measure smaller things. As A. W. Hull of General Electric expressed it a number of years ago, "the main function of electronic devices in aiding research is to make possible the measurement of smaller things than could be measured before with less disturbance, by the measuring rod, of the thing measured." The uncertainty principle teaches that the ultimate limit of smallness that can be observed, is reached when the magnitude to be measured is smaller than the disturbance caused by the application of the measuring means. Electronics makes it possible for us to approach this ideal by supplying us with the lightest known measuring agents, electrons and photons.

Strangely enough, however, although electronics has extended virtually all methods of measurement, it has not necessarily displaced a number of the older more fundamental principles and devices used in measurement. In the measurement of temperature, for example, regardless of how many electron tubes may be incorporated in a modern temperature measuring device, the primary elements are still the same familiar thermometers or thermocouples we have always used. The familiar basic temperature measuring devices, expanding metals, liquids or gases, thermocouples or resistance thermometers, now, frequently work through electronic amplifiers so that indicators and recorders can carry more sensitive scales.

True Electronic Temperature Measuring Devices

This does not imply that more fundamental, truly electronic temperature measuring devices may not be developed in the future; indeed, in the writer's opinion this offers one of the most opportune fields for research and development. It has been suggested that present-day thermometers and thermocouples might be replaced by gas- or vapor-filled electron tubes which would be sensitive to temperature changes, or, it is easily possible to conceive a temperature sensitive crystal oscillator whose output frequency would be a function of the temperature.* Most ordinary types of crystal oscillators are sensitive to changes in temperature. In communication equipment this is an unwanted condition but it might be possible to put it to good use in a temperature measuring system.

In some branches of the field of measurement, purely electronic measurements are in use. In the measurement of light, indeed of all electromagnetic radiation in the frequency range above that of the infrared, purely electronic measurements are in use, not only in measuring intensity of

*"Opportunities for Electronics in Industrial Temperature Instrumentation," by M. F. Behar. *Electronics*, Vol. 15, Dec. 1942, pages 72-76, 163-166.

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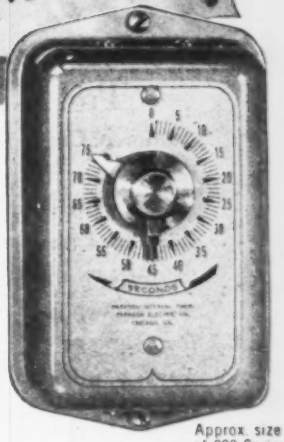

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radiation but of quality as well. An ordinary photographic exposure meter for example employs an electronic method of measurement. Radiation falling upon electronic-emitting surface of a photocell is converted directly into an electric current capable of being measured by ordinary ammeters or voltmeters.

In many measurement applications the photocell acts as an intermediary between the thing which is to be measured and the indicating or recording instrument. The following description of an electronic speed indicator and control system is an example of this kind:

Several years ago, physicists in the laboratory of the U. S. Department of Public Health in Washington were confronted with an unusual but interesting problem. This involved the exact measurement and control of the speed of an ultra-centrifuge rotating at 100,000 rpm. The centrifuge used in this laboratory was driven by a stream of compressed air and, like others of its type, rotated on a similar stream for its bearing. The obvious method of measurement, that of using a neon-lamp stroboscope operating at a submultiple of the rotational speed in this case was open to three objections: (1) the method would not permit accurate measurement rapidly because the submultiples would be too close together on the commercial forms of stroboscopes available; (2) safety considerations prevented the operator from being too near the centrifuge when operating at such speeds, and (3) it provided no means of controlling the speed.

The method finally proposed used a General Radio Co. Electronic Frequency Meter to indicate the speed. A beam of light is reflected from the surface of the rotating element on the centrifuge and falls on a phototube. A black spot painted on the rotating surface interrupts the light once each revolution. The amplified output of the phototube is then applied to the electronic frequency meter which indicates the speed directly in revolutions per second. Carrying the project one step further, a marginal relay in the d-c. instrument circuit is then used to control the pressure of the air stream driving the centrifuge, providing an automatic speed control.

This application of electron tubes to the solution of a difficult practical problem shows how the electron tube can be made to accomplish things than cannot be done in other ways or as simply. This, it is true, was an unusual problem, one that does not occur very often and this was one of the reasons it was cited as an example. Another reason for presenting it here, however, is because it involves the use of all of the fundamental types of tubes we have considered in these articles. As will be shown, it makes use of the photoelectric tube, the cold-cathode glow tube, the high-vacuum amplifier and the gas-filled hot-cathode tube in both the diode and triode forms.

The circuit arrangement is shown in Fig. 180. At the left is shown the phototube which picks up the light impulse from the rotating element of the centrifuge. The output of this tube (which, in common with the output of any photo-

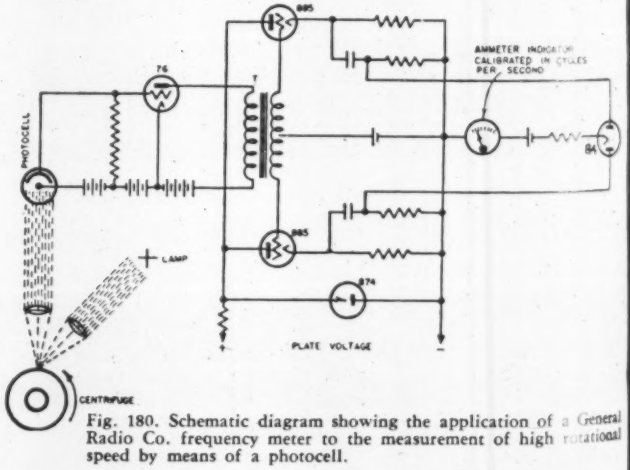

Fig. 180. Schematic diagram showing the application of a General Radio Co. frequency meter to the measurement of high rotational speed by means of a photocell.

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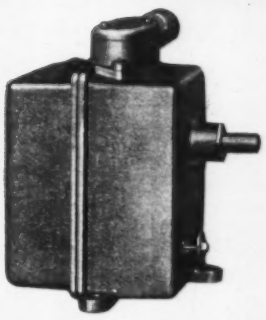

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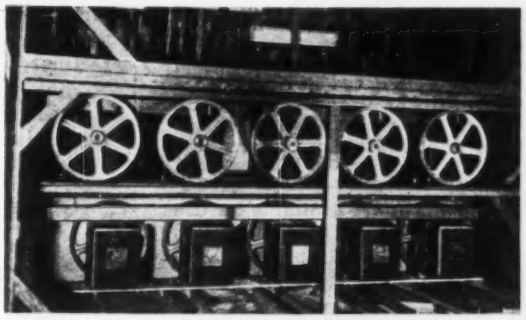

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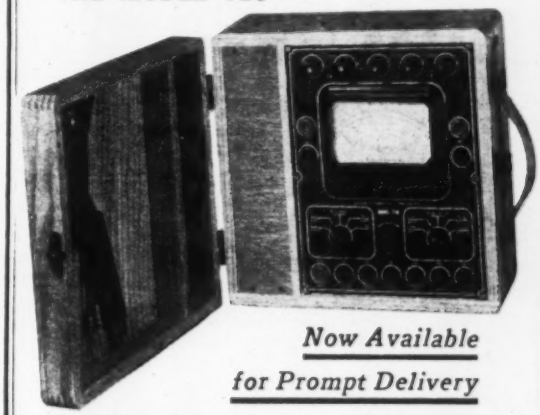

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tube, is extremely weak) is amplified by the 76 triode amplifier. This is a high-vacuum amplifier. The amplified output of this tube is delivered to the input transformer, *T*. The secondary of this transformer is connected to the grids of two gas-filled triodes, as shown. When the alternating voltage of this secondary is applied to the grids of these gas-discharge tubes, each tube becomes alternately conducting and non-conducting. At each transition of the current from one tube to the other, a current pulse is sent through the indicator circuit. Since the magnitude of each pulse is the same, the average current through the ammeter is directly proportional to the number of pulses and therefore can be calibrated directly in pulses or cycles per second. The 84 full-wave high-vacuum rectifier serves as an automatic switch which switches the indicator circuit from one side to the other.

The 874, as may be recalled from a previous article,* is a cold-cathode voltage regulator tube used to keep the applied plate voltage to the 885's below a certain limiting value. The actual plate supply circuit which furnishes the direct current for the 885's is not shown but this in the actual frequency meter uses an 82 full-wave mercury-vapor rectifier.

Thus, it will be seen, practically every type of tube considered in the foregoing chapters is used in this one circuit. Let us list them again:

1. The photoelectric tube
2. The cold-cathode grid-glow tube (874)
3. The high-vacuum amplifier (76)
4. The high-vacuum rectifier (84)
5. The mercury-vapor rectifier (82)
6. The gas-discharge triode (885)

Light Beam Linkage

Aside from the interest the application just described has because of the tubes employed, the system is improved because of the phototube arrangement which forms the connecting link between the centrifuge and the frequency meter. The result might have been accomplished in other ways but nothing could be simpler nor more positive than the light beam and the photocell. The light beam exerts the least drag upon the movement of the rotating parts of any arrangement we can conceive; in terms of human understanding it is zero. Here, we have an actual example of what Dr. Hull meant in his statement referred to above. It is improbable that mechanical contacts, however small and well designed, could have been practical—the speed was too great.

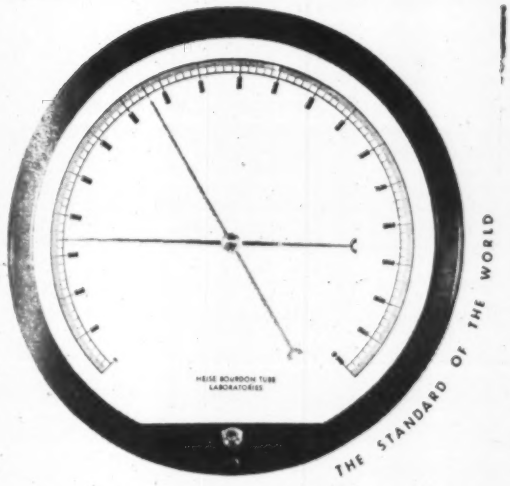
This principle of using light beams and photocells as links in measuring systems is one that has been found useful in the design of many instruments, particularly in recorders of various kinds. These applications will be described in detail in subsequent articles, but in each case it will be possible to describe only a few examples in each different class. To describe the thousands of devices and methods for measurement in use today would require volumes and any such attempt would be out of date almost before it could be published.

In the application of electronics to instrumentation, we are concerned less with the fundamental principles of measurement than we are with methods for extending and improving these fundamental principles. In the measurement of length, for example, the simple and basic machinists' micrometer finds its precision multiplied several times by using an electron tube to detect contact instead of the sensitive touch of the operator. This principle of detection, naturally, is applicable to a whole group of measurements. Similarly the light-beam link between a mechanical system and an electrical system described above is applicable to a great variety of measuring devices.

Because of these broad applications of electronic principles to whole groups of measuring devices, it is not desirable to discuss the application of electronics to instrumentation with respect to the various systems available for the classification of measurements.

Fundamentally, it is possible to reduce all units of meas-

*July 1944.



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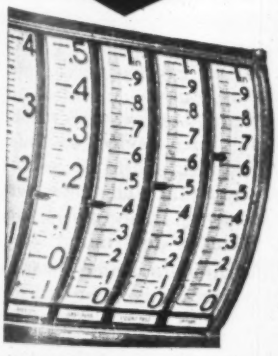

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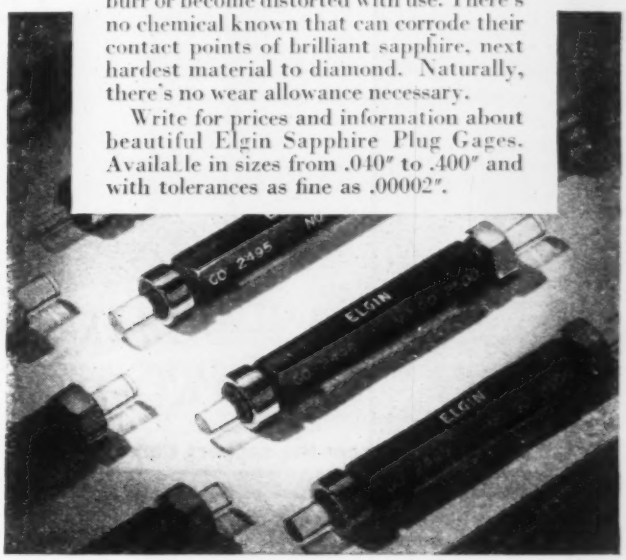

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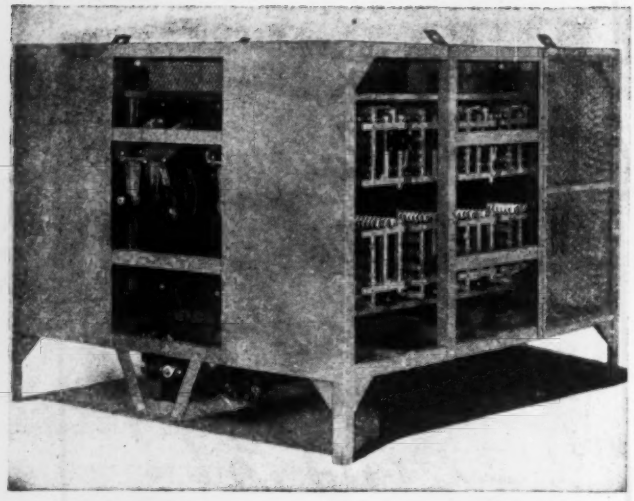

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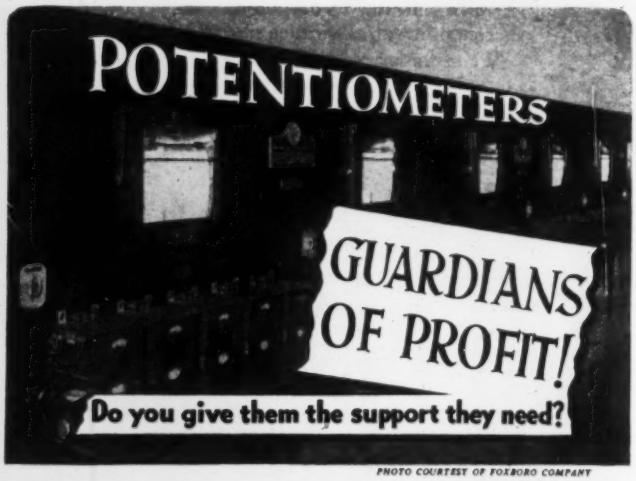

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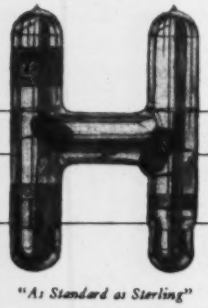

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ment to the three basic elements of either of the two systems of units in general use in the English speaking countries: the so-called British system having the yard and the pound as standard units of length and mass, called the foot-pound-second (FPS) system; and the centimeter-gram-second (CGS) system, having the centimeter and gram as standard units of length and mass, and known as the metric system. The fundamental unit of time is the same in both systems, namely, the mean solar second, one-86,400th of a mean solar day.

All the various units which are used in practical physical measurement are based upon these three concepts, length, mass and time. Upon them are based the two electrical system of measurement, the electromagnetic system and the electrostatic system.* Thermal units are also expressed in terms of the CGS or FPS systems of units. Heat is a form of energy which can be expressed in units of energy of any kind. A B.T.U., for example, is the equivalent of 778 ft.lb. Temperature is a measure of the condition of a body with reference to its capability to communicate heat to other bodies.

In classifying instruments, however, it is not desirable to adhere too closely to the three basic units; it is better to list those concerning temperature and electrical magnitudes separately, as follows:

1. Instruments for measuring
   - A. Length
   - B. Mass
   - C. Time
2. Instruments for measuring electrical magnitudes
3. Instruments for measuring other physical magnitudes, such as
   - A. Temperature
   - B. Humidity, viscosity
   - C. Velocity
4. Instruments for measuring electromagnetic radiation, such as heat, light, x-rays, etc.

With a system as this, all such devices as rulers, micrometers, interferometers, thickness gages, etc., would be classified under 1 A. Such devices as speed indicators, tachometers, counters, etc., would be classified under 3 C. Such classifications are quite definite. Others might prove more difficult. A device for measuring temperature, for example, might be grouped under 3 A, that is, temperature measuring instruments, or under 4, depending upon the nature of the device. A radiation pyrometer would probably be classified as an instrument for measuring electromagnetic radiation, since heat waves are electromagnetic radiations.

The system of classification just described may be regarded as an absolute system, since it is based upon our absolute units of measurements. For practical purposes, another system based upon a different set of principles may prove more convenient. For example, all instruments can be grouped under three headings as follows:†

1. Instruments for the measurement of quantity
   - A. Absolute
   - B. With respect to time
2. Instruments for the measurement of quality
3. Instruments for the measurement of condition

As indicated, instruments for the measurement of quantity (Group 1) can be divided into two groups: first, those for the measurement of quantity in bulk or in total, and second, those for the measurement of quantity with respect to time. The first subdivision includes such devices as scales, cubic measures, integrating devices, etc., while the second has reference to devices such as ammeters and flowmeters. These are the instruments used primarily in accounting and cost finding but are also used in efficiency determinations.

Under Group 2 are included instruments which measure the quality of things and under this grouping may be listed calorimeters, gas analyzers, hydrometers, photometers.

*The electromagnetic sub-system was established on the basis of the unit magnetic pole, such that it repelled its prototype at a distance of 1 cm. with a force of 1 dyne. The dyne, of course, is derived from the centimeter, the gram and the second. The electrostatic sub-system was similarly established on the basis of unit quantity of electricity such that it repelled its prototype at a distance of 1 cm. with a force of 1 dyne.

†*Power Plant Engineering*, January 1935.

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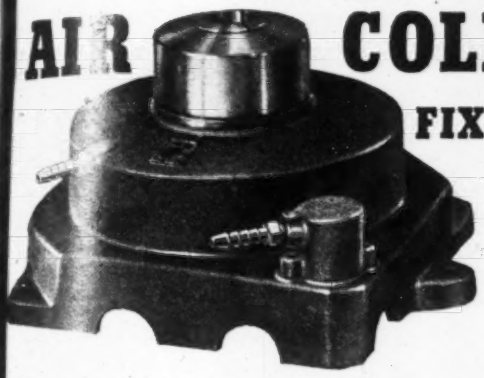

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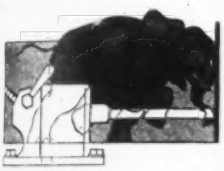

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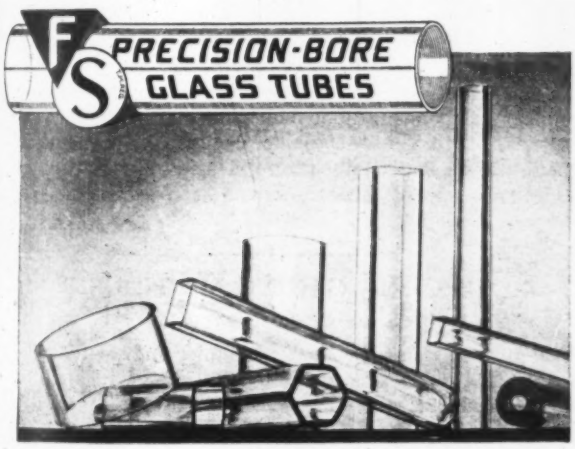

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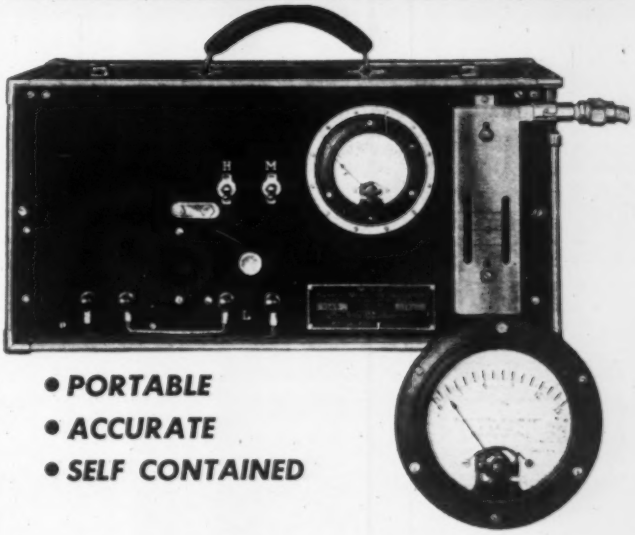

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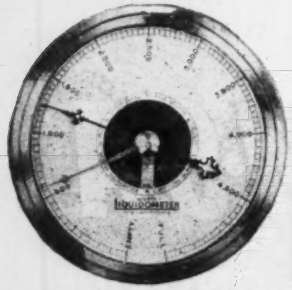

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These instruments are usually used in maintaining proper service requirements.

Finally we have the group used in measuring the condition of things, temperature, pressure, speed, voltage, etc., and here we may list thermometers, voltmeters, pressure gages—instruments used primarily in maintaining safe operating conditions but of course also useful for other purposes.

The two systems of classifying instruments have been considered in some detail here to show how difficult it would be to attempt using them in the classification of electronic applications. Even a superficial study of electronic instruments will show that the application of electronics to instrumentation has little bearing on such systems of classification. It will be found that the electronic principles involved bear no relation to the commodity or value being measured. Thus, the electronic, and photoelectric recorders described in a later article can be used to record the measurement of almost any variable magnitude—voltage, current, phase relationship, temperature, thickness, viscosity, etc. Similarly, certain types of electronic indicators are adaptable to the measurement of widely different quantities and qualities.

The fundamental functions of electronics in the field of instrumentation, therefore, are more logically listed under the following general headings:

1. Conversion
2. Amplification
3. Sensitive contact
4. The photoelectric effect
5. Light-beam linkage
6. Cathode-ray action
7. Oscillation

To this list, one may be inclined to add the piezoelectric effect, since many electronic instruments make use of this effect, but since the piezoelectric effect was discovered long before the science of electronics was developed, it is better to regard it as a fundamental method of measurement, like the thermoelectric effect. Both the piezoelectric effect and the thermoelectric effect are undoubtedly electronic in nature.

Thus it is seen that the applications of electronics in the field of instrumentation can be grouped under a comparatively few simple headings. In some cases one group depends upon another: the light-beam linkage principle, for example, is dependent upon the photoelectric effect. Similarly the sensitive contact principle used in electronic micrometers is dependent upon amplification but, in each case, it is desirable to list these functions separately.

(To be continued)

ELECTRIC GAGING METHODS

(Continued from page 605)

This gage is extremely compact, simple, and robust. It has had a wide application in automobile gages, in small controls and the like.

A novel and extremely useful method for measuring the thickness of metallic plates when only one side is available is illustrated in Fig. 78. It may be applied to any conducting material—not necessarily metallic. If a set of four electrodes be set up as illustrated, and a current introduced into the specimen through the outer two of the four, while the potential difference between the inner two is measured with a sensitive galvanometer, a definite relation can be established between the potential-current ratio and the thickness of the metal. There are certain experimental difficulties which require precautionary measures, but the method has a successful record.[175] The errors depend almost entirely upon the care exercised in use; however, one basic difficulty is that if the two sides of the plate are not

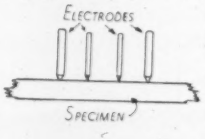

FIG. 78

(175) B. M. Thornton and W. M. Thornton. Measurement of the thickness of Metal Walls from One Surface Only, by an Electrical Method. *Proceedings of the Institution of Mechanical Engineers* (London), Vol. 140, 1938, pages 349-398.

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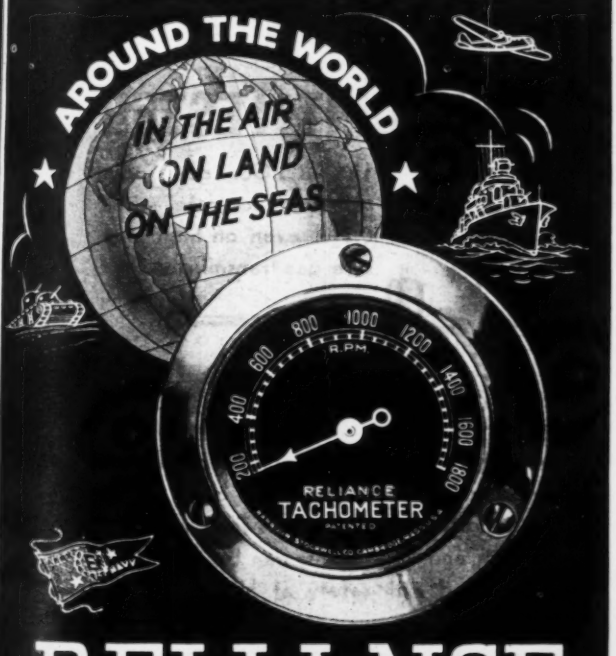

RELIANCE
PRODUCTS
BARBOUR STOCKWELL COMPANY
CAMBRIDGE, MASSACHUSETTS

parallel, a single reading is quite misleading. In such a situation, a set of several readings at different orientations must be made, and the results analyzed. Another necessary condition is that the electrode spacing be rather large compared to the thickness of the plate.

A novel method, based upon the same principle as that just described, has been used for measuring the temperature of boiler tubes, in inaccessible locations. The temperature of the metal affects its resistivity, as has been described, and the resistance (hence the resistivity) can be measured by passing a current through the body and measuring suitable potentials.[176]

Likewise, such a method has been employed to check the composition and quality of small metal parts. In certain respects, it resembles the rail- and cable-testing methods previously described, but whereas those methods were designed to locate discontinuities in sound material, the one here referred to depends upon the change in properties of the material due to composition or heat-treatment to change the resistivity of the material.[177] *(To be continued)*

(176) J. H. Marchant. An Electrical Method of Determining the Mean Surface Temperature of Tubes. *Transactions American Society of Mechanical Engineers*, Vol. 59, 1937, pages A-16-20.

(177) Haakon Styri. Testing of Ball Bearing Races by Electric and Magnetic Methods. *Proceedings American Society for Testing Materials*, Vol. 26, part II, 1926, pages 148-176.

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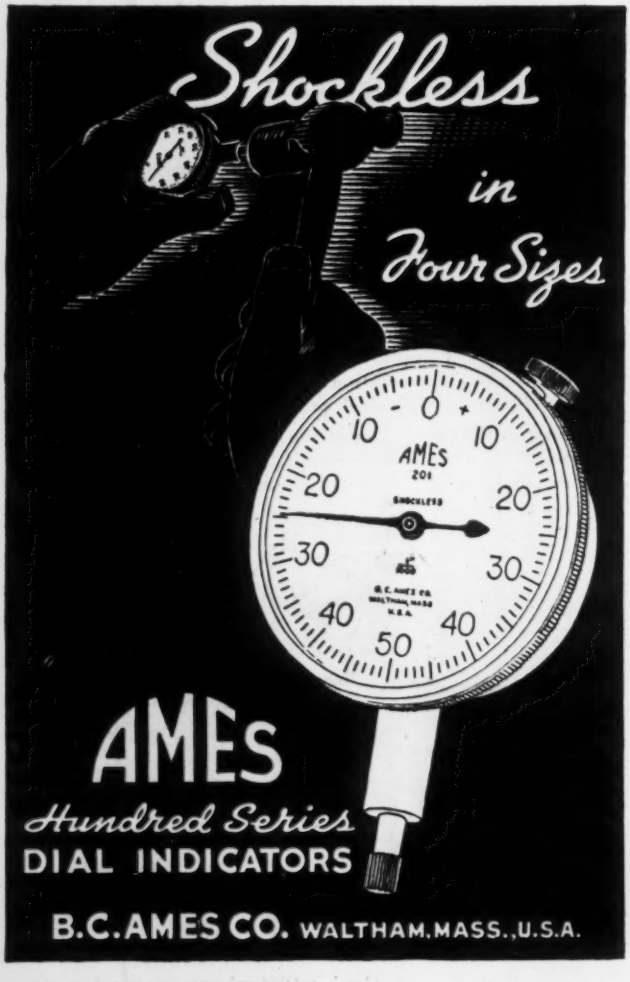
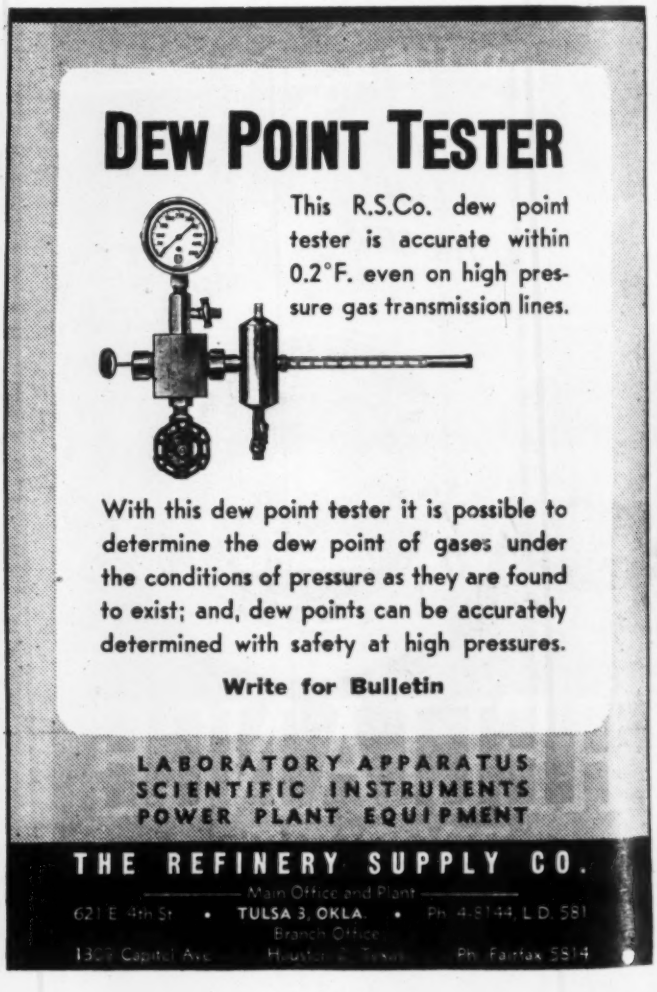


Fuel-Saving Starts With CONTROL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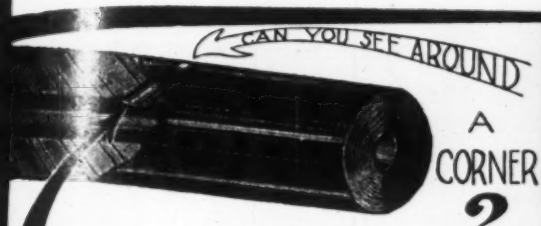

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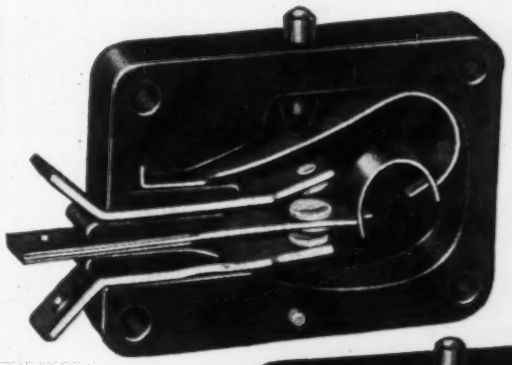

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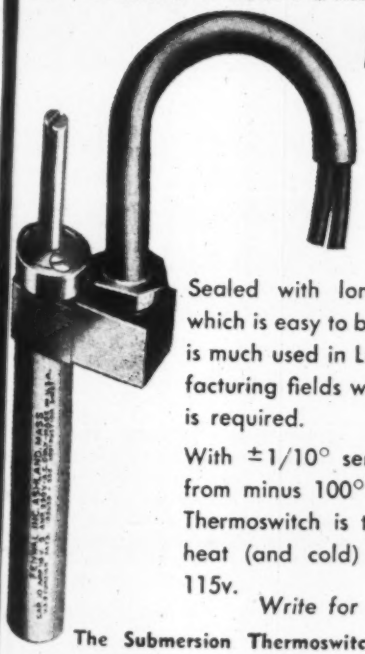

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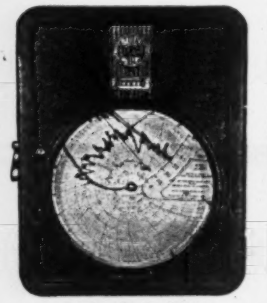

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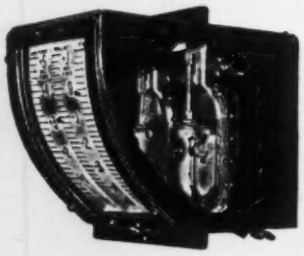
Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



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Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

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The Month's NEW INSTRUMENTS

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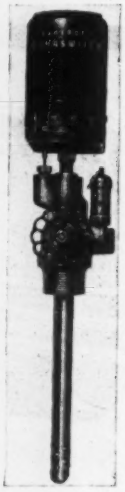
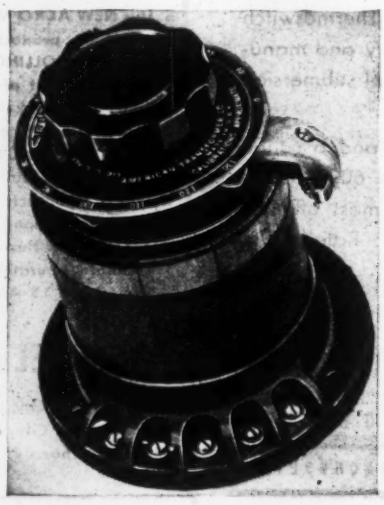
"Compressor-trol"



New "Ashcroft Compressor-trol" is said to be an instrument which combines seven devices for the control of compressor operations. It is said to eliminate necessity of using pipe and pipe fitting, simplifying installation and reducing possibility of air leakage. It is made in three sizes: ½", ¾" and 1¼" (sizes determined by inlet connection) to cover all requirements of tank-mounted compressors up to 15 h.p. or 60 ft.³/min. Equipped with "Ashcroft Duraswitch," with either an electric or mechanical attachment for operating the two-way unloading valve mounted on the "Compressor-trol" casting. Muffler on compressor discharges into tank. Muffler acts to break up discharge and to disperse air in a manner said to insure adequate mixing with cooler gases in tank to reduce temperature and moisture content before delivery. Combined "Ashcroft Duraswitch and Gauge" has heavy-duty gearless movement, slide rule dial, horizontal self-draining and non-freezing Bourdon tube, and entire gage is completely removable and replaceable in case of accidental damage. Can be furnished in all standard pressure ranges.—*Electro-Mechanical Division, Manning, Maxwell & Moore, Inc., Bridgeport, Conn.*

Voltage-regulating Transformer

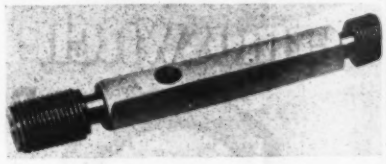
New "Model TH Transtat" a-c. voltage regulator is smallest "Transtat," is said to have high rating to size ratio and to incorporate "a number of noteworthy developments." Brush arm is of unique design:



a die casting which permits good heat dissipation, provides a simple means of changing brushes and protects commutator against short circuiting contact with brush holder. Shaft is independent of brush arm assembly and can be removed by drawing one pin. Thus, unit can be quickly changed from panel mounting to table mounting or ganged with other units for polyphase or simultaneous single-phase control. By employing a phenolic thermosetting plastic of new design, high dimensional conformance is said to be assured and accidental lead shorting is prevented. Among refinements: vinyl acetal insulated wire, impregnation of core and coil with a synthetic phenolic resin varnish of polymerizing type, followed by baking, corrosion-resistant fittings, and new dual mounting arrangement for open delta three-phase control minimizing waste space.—*American Transformer Co., 164 Emmet St., Newark, N. J.*

Carbide Thread Plug Gages

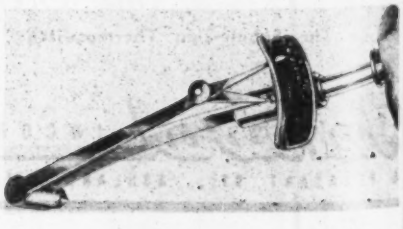
New line of carbide thread plug gages is said to be complete and it is claimed that extreme care in grinding operations makes these gages accurate to "exceptionally close



tolerances." Wear-resisting properties of carbide make possible continued accuracy over longer periods of time, and permit more gaging operations to be performed before checking or refinishing than with steel. Three styles are offered, made to American Gage Design standards. Solid carbide is used for the smaller size gaging members. Larger sizes have a carbide bushing over a steel body. All gaging members are ground from solid carbide. Available sizes range from 0.112" to 3", accurately ground to Class X or Class Y tolerances.—*Jansson Gage Co., 19208 Glendale Ave., Detroit 23, Mich.*

"Three-sense" Torque Wrench

New "Sensory Torque Wrench" is said to represent culmination of seven years of extensive research: a wrench that "in use is faster than thought," will stand all ordinary shop abuse and yet remain dead accurate. New "Sensory" model closely resembles maker's previous models in appearance.



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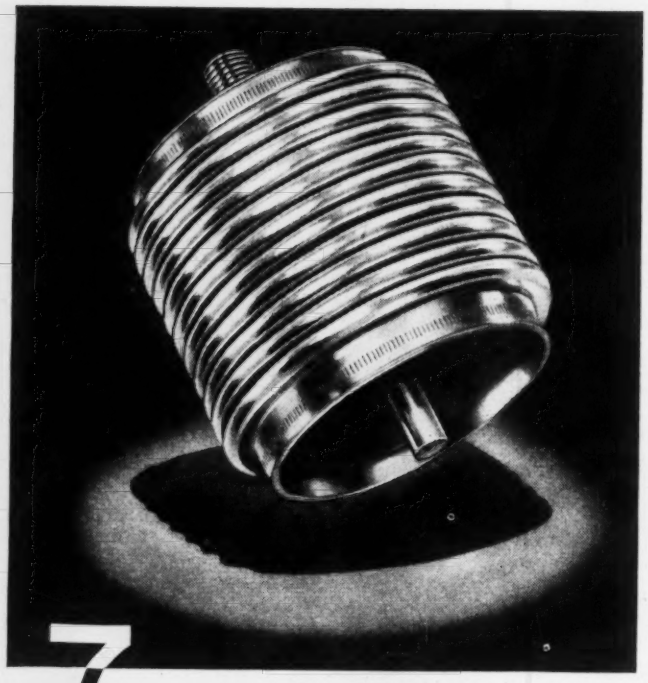

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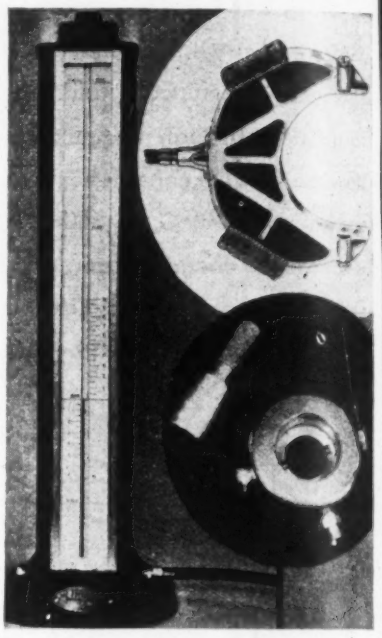
Air Gages for External Diameter

New external-diameter gages have been developed which utilize air-flow principle and operate in conjunction with "Metricator" instrument (see *Instruments,* July 194



pages 453-454 for detailed technical description of "Metricator" Gaging System). New gages are made in either indicating ring or indicating snap gage type, depending on size of external diameter to be measured. Size variations as small as 25 millionths of an inch can be readily detected. For inspection of parts requiring extreme accuracy, amplification can be increased so that parts can be classified into groups of 10-microinch size difference without operator fatigue. At an amplification of approx. 4000, range is 0.002". For parts ground in centerless grinder, maker recommends new indicating rings with three equally-spaced measuring orifices: these are said to make possible easy and rapid detection of "three-cornered" condition and other conditions which can only be detected with great difficulty by ordinary gaging methods. New gages are said to be of considerable assistance in determining sources of assembly difficulties as well as in remedying faulty machine operations. — *Dept. 35, Metrical Laboratories Inc., 417 Detroit St., Ann Arbor, Mich.*

Re-designed Circuit Breaker

New 100-ampere "F-frame De-ion" fuseless circuit breaker requires less space than did preceding models, permits lighter structures for distribution panelboards, built-in applications and bus duct plug-ins. All ratings are available in one compact breaker with uniform pole spacings and terminal arrangement, providing complete interchangeability between ratings. New "F" frame is said to permit for the first time a 100-amp. 600-volt a-c. or 250-volt d-c. breaker in space formerly required by 50-

...p. 600-volt a-c. or 250-volt d-c. rating. ...quipped with thermal and instantaneous ...agnetic trip elements, new breaker per... ...its maximum loading of circuits and fast ...sumption of interrupted service. Contact ...essure increases with wear, thereby pro... ...ging life of contacts and breaker. Silver ...oy contacts are said to give increased ...ntact life with lower wattage loss. Spe... ...al alloys also prevents "freezing." Both ...o and three-pole units are available.—*Westinghouse Elec. & Mfg. Co., P. O. Box ...s, Pittsburgh 30, Pa.*

Fine-adjustment Height Gage

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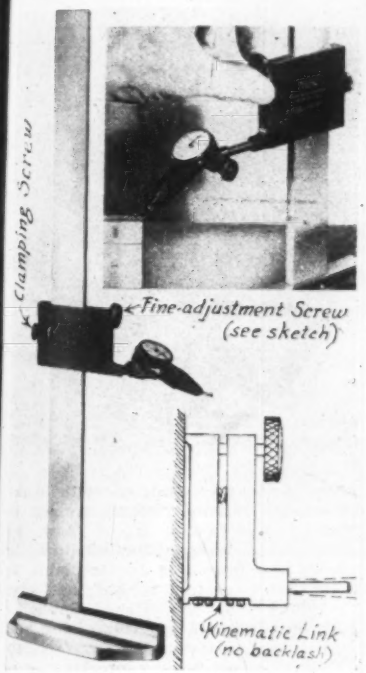
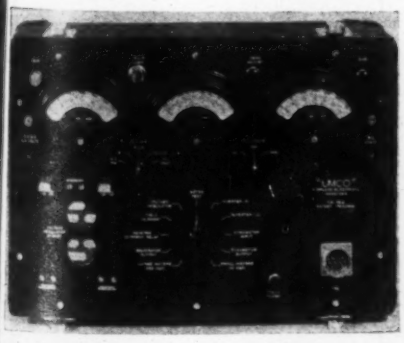


...brake, which prevents its dropping when ...lamping screw is loosened; and also with ...a fine-adjustment feature of kinematic de... ...ign (see sketch) whereby the dial indi... ...cator can be set to gage blocks without ...need of "tapping" or other final manipula... ...tion. Outfit comprising 20" stand, bracket, ...nd English or Metric "Testmaster" is sup... ...plied in wooden case. New fine-adjustment ...bracket is available separately: it will fit ...any height gage having an upright 1¼" × ...¾" and it has a 0.219" diam. stud on which ...to attach a dial indicator.—*Federal Prod... ...ucts Corp., 1144 Eddy St., Providence, R. I.*

Aircraft Electrical Analyzer

New "Umco Aircraft Electrical Analyzer" ...is a portable unit whereby it is claimed that ...that "all wiring and electrical troubles on ...75% of American aircraft can be analyzed



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Decibel Meters
Telephone Transmission Testing Equipment
Wheatstone Bridges
Fault-Location Bridges
Kelvin-Wheatstone Bridges
High-Voltage Measuring Apparatus
Low-Resistance Test Sets
Kilovoltmeter Multipliers
Rotary Selector Switches
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Portable Galvanometers

Shallcross Portable Kilovoltmeters in types up to 30 KV are available for rapid delivery.

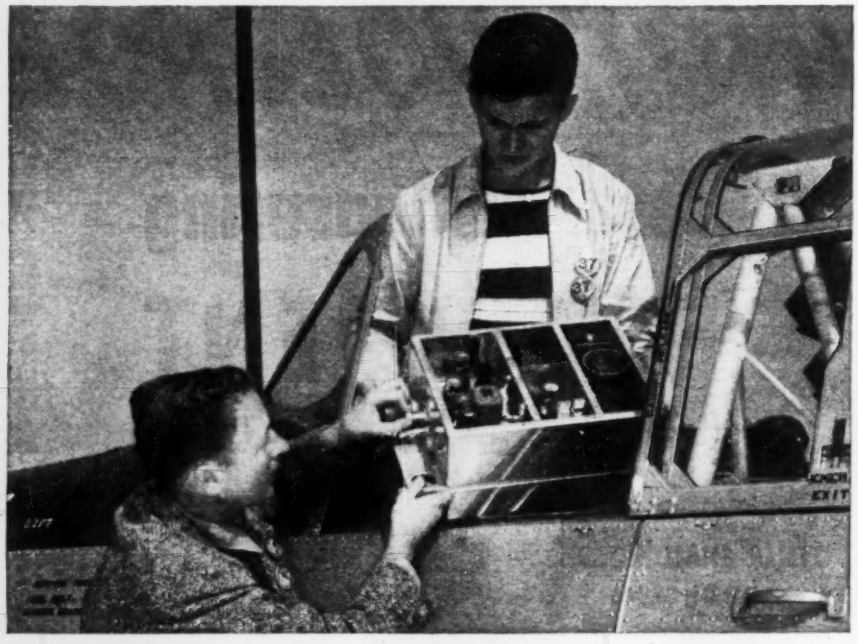
From Kilovoltmeter Multipliers to corona-protected resistors, Shallcross offers a complete line of measuring and test equipment, as well as many components, all especially designed for the high voltages now coming into more general use. Much of this equipment cannot yet be cataloged completely. Much more is especially designed to meet customers' specifications based on the rapid advancements in radar, television, radio transmitting, dust precipitators, power transmission, and similar equipment.

Bring your high-voltage measurement problems to Shallcross!

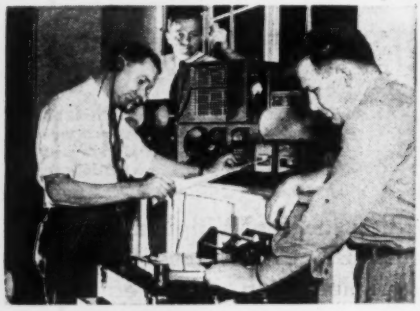
SHALLCROSS MFG. CO.
DEPT. IS-104, COLLINGDALE, PA.
ENGINEERING • DESIGNING • MANUFACTURING

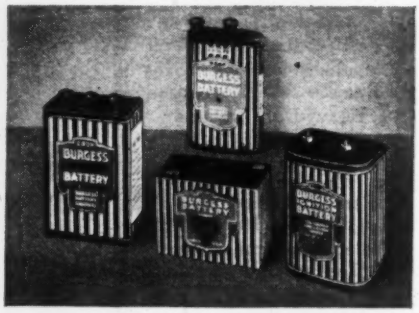
PORTABLE POWER PROBLEMS

THIS MONTH—AUTOMATIC FLIGHT RECORDER

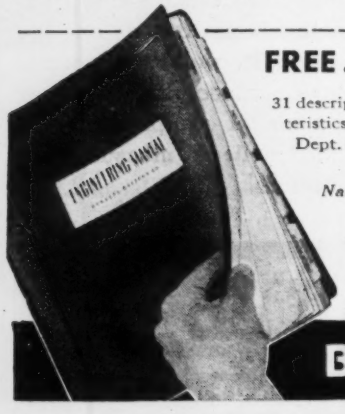


THE RADIO FLIGHT REPORTER accurately supplements test-pilot observations on performances of new planes. From a 70-point system of gauges, vibration, strain and engine performance readings are flashed to the ground receiver. When this amazing device was developed by Consolidated Vultee, the *portable* power was supplied by Burgess Batteries, used in all laboratory testing and development work at Vultee Field.





AT THE GROUND STATION, a Burgess-powered receiver records all data on ticker tape, sound film and disks. Analysis of film and disks permits engineers accurately to determine the planes' performance under varied conditions. New, special purpose batteries are constantly being developed by Burgess engineers. Let them solve *your* problems whenever they involve industrial applications of portable power.



FREE . . . 80-PAGE ENGINEERING MANUAL!

31 descriptive pages, 25 charts and 36 data tables on dry battery characteristics for electronic applications. Tabbed for ready-reference. Write Dept. 4 for your *free* copy. *Burgess Battery Company, Freeport, Ill.*

Name .....

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City ..... *State* .....

BURGESS BATTERIES

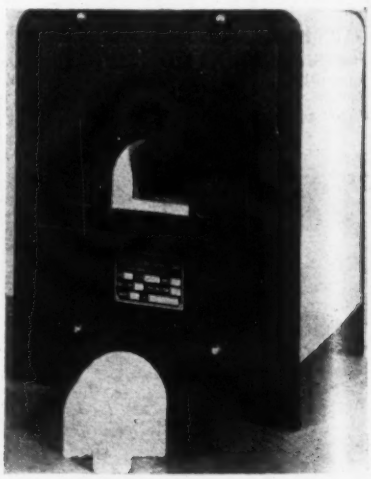
and located. New unit can also be used for checking open circuits, short circuits and measuring resistances of any circuit element. A tee adapter is inserted in the circuit to be tested; the selector switch on the unit is turned to that specific circuit and the test can be completely made. New analyzer is said to be especially advantageous for testing and adjusting voltage regulators and reverse current relays. Unit complete with all accessories weighs approx. 25 lbs. *United Hydraulic Mfg. Co., 2400 E. 57 St., Los Angeles 11, Calif.*

Four-way Valve for Position Control

New "No. 13261" remote-positioning four-way control valve eliminates cable control, push-pull rods and "old-fashioned mechanical controls," permits regulation of high-pressure hydraulic systems with maker's "ISOdraulic" remote control system. Unit illustrated has a 16 g.p.m. flow, 3,000 lbs./in.^{2} and is designed for ¾" lines. Units for flows and pressures are available. It is claimed that important weight and installation savings are accomplished through use of "ISOdraulic" controls comprising an independent system operating from −65°F. to 165°F. with either master or slave or both at either extreme.—*Adel Precision Products Corp., Burbank, Calif.*

Laboratory Furnaces

New line of high-temperature laboratory furnaces with maximum temperatures of 2750°F. and operating temperatures of 2500°F. is said to be complete. These furnaces are for industrial and school laboratories where materials are to be heated in an oxidizing atmosphere at temperatures above those attainable with metallic elements; also for applications where special condi-



ons are involved, such as rapid heating, or sating in special atmospheres not injurious silicon carbide. New furnaces are equipped th a silicon carbide muffle and are heated th Globar Brand non-metallic heating ments located above and below the muf- to assure uniform distribution of heat. ther a plug type or a counter-balanced r is available. Furnaces are made in rious sizes with chamber dimensions of " high × 3½" wide × 5" deep, and " high × 6" wide × 18" deep. They are ailable for bench mounting or with legs r floor mounting.—*Harper Electric Furnace Corp., Niagara Falls, N. Y.*

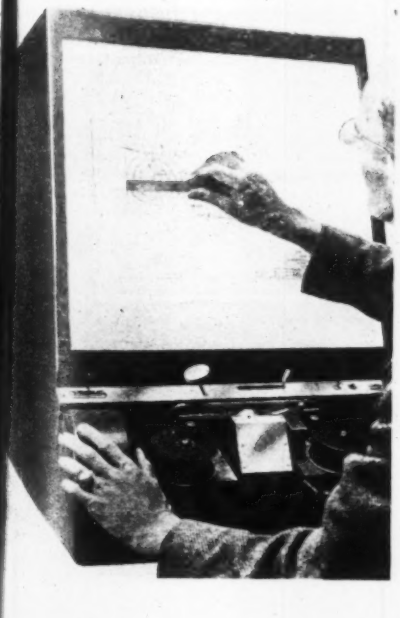
Flow-rate Indicator

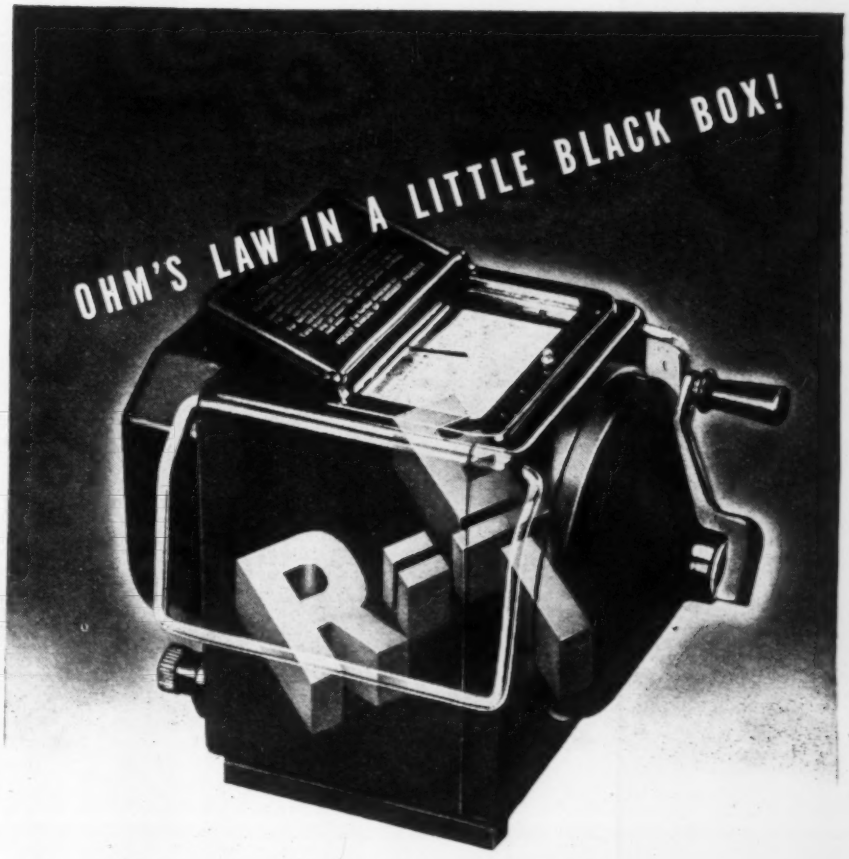
New "Mite Rate of Flow Indicator" (differential flow type) employs a rupture-proof bellows which takes the place of the ercury column commonly used in instru-

ents of this class. It will, therefore, withand extreme over-ranging without damge. While compact in size, (3¼" diam. d 4" long) it can be furnished to handle e pressures to 1,000 lbs./in.²—*Morey & ones, Ltd., 922 South Hemlock St., Los ngeles, 22, Calif.*

Microfilm Process

New "Microcopy Translite Hi-Reduction rocess" is said to be a simple and economal method of condensing and preserving tal records for an indefinite period. It is escribed as the application of microfilming engineering drawings, documents, etc., pt in industrial manufacturing plant files. ecause of a high-fidelity translite feature, is said to be particularly adaptable to





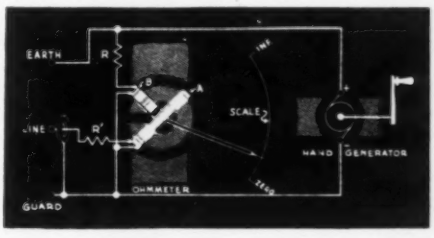
. . . THE "MEGGER"* INSULATION TESTER

The dependability of the "Megger" Instrument for measuring electrical insulation resistance is like the constancy of Ohm's Law, on which principle it actually operates. This "Megger" method for testing insulation resistance is simple and remarkably accurate. The principle is precisely the same as it was forty years ago and yet it meets today's needs perfectly.

You will find the same ruggedness and dependability in U.S.-made "Megger" instruments that the electrical industry has known for so long a time.

Let us send you full details on various types and ratings. Ask for Bulletin 1685-I.

* *Trade Mark Reg. U. S. Pat. Off.*



PRINCIPLE OF OPERATION

In what we term a cross-coil true ohmmeter, two coils are mounted in fixed relation to each other on the same pivot-and-jewel moving system in the field of a permanent magnet. "Current" flows in coil A and "potential" in coil B, and they are connected so that their respective torques oppose each other. Since there are no control springs, the opposing coils give a true ratio of E/I, and ohms (or megohms) are indicated directly by a pointer over a scale. The readings are independent of the voltage of the hand-driven d-c generator, because any change in the voltage affects both coils in the same proportion.

JAMES G. BIDDLE CO. 1211 ARCH ST. PHILA. 7, PA.

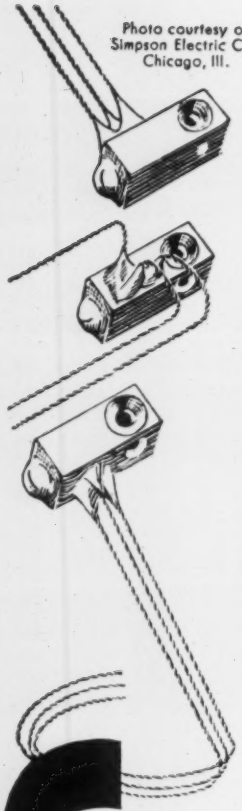
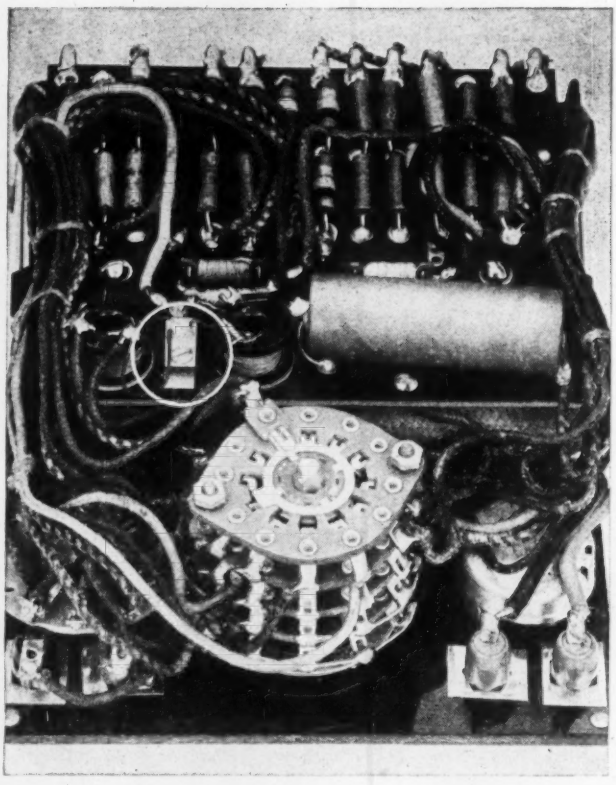


Photo courtesy of Simpson Electric Co. Chicago, Ill.



Conant's standard midget

(series 160) LEADS A 3-WAY LIFE!

Yes, indeed, the standard midgets of the Conant family (160" diameter discs) are versatile. The unique full metal case protects the rectifier assembly from damage and permits mounting in *any of three positions* with a single screw. Combining the three positions with angular mounting permits the leads to extend from the rectifier in almost any direction. Thus, one standard rectifier serves for all models. Further protection is provided by a special moisture proof seal.

Design and construction of Series 160 are the result of years of experience and close cooperation with instrument manufacturers.

For all applications requiring high sensitivity operation over an extended frequency range, you can count on Conant's Standard Midget–Series 160.

Instrument Rectifiers

CONANT ELECTRICAL LABORATORIES

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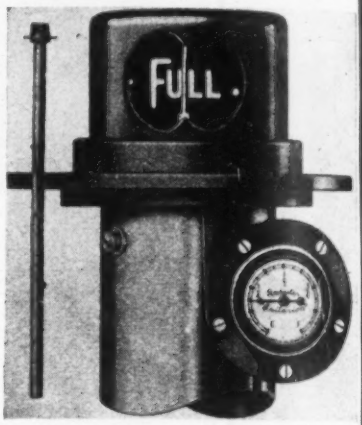
85 E. Gay St., Columbus, Ohio
600 S. Michigan Ave., Chicago 5, Ill.
1215 Harmon Pl., Minneapolis 3, Minn.
2017 Grand Ave., Kansas City, Mo.
7935 Eustis St., Dallas 18, Texas
4018 Greer Ave., St. Louis, Mo.
1526 Ivy St., Denver, Colo.
4214 Country Club Dr., Long Beach 7, Cal.
4205 N.E. 22nd Ave., Portland 11, Ore.
Caixa Postal 930, Sao Paulo, Brazil
50 Yarmouth Rd., Toronto, Canada

engineering drawings, in pencil or tr parent paper. "Microcopy" reduction ph graphs being on a continuous roll, "Mic copy" master-files are said to become ta per-proof, extraction-proof and substitutio proof. For reading "Microcopy," a "Mic copy Multiple-magnification Viewer" is su plied in various models, one of which illustrated. Viewer, operated on a moti picture film projector principle, is operat simply from a control panel. It facilita finding locations on films by permitting largements to be made on the screen, well as permitting any portion of the fra to be centralized within the frame for eas reading.—*Microcopy Corp., 2060 W. O Ave., Burbank, Calif.*

Liquid Level Gage

New leakproof liquid level gage is signed for use in bomb bay fuel tanks, d not employ conventional lever type f which swings through an arc, but utili



one which, with its attached Alnico perm nent magnet, travels vertically up and do within a tube. Tube has a spirally cut s which guides and rotates float. Motion float is imparted to dial indicator by ma netic action through non-magnetic me floor which separates dial chamber fr tank interior. Large white fluorescent phosphorescent markings stand out again the dull black dial background (or bla figures on white background). Dial swing through 300° arc. Either side view or t view dials. New gages are said to be ideal suited for applications where ordinary flo and lever type action might be impeded tank wall.—*Rochester Mfg. Co., Rochest New York.*

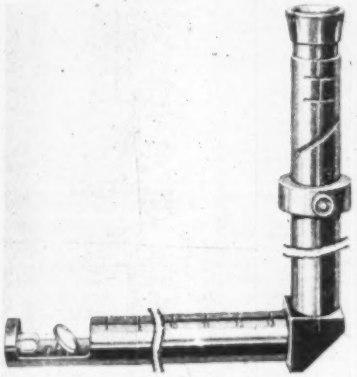
Electrocardiograph

New EPL Electrocardiograph is an in less direct-recording instrument said to gi "instantaneous standard readings." It h been designed to eliminate all photograph procedures. It is said that ordinary inte fering electrical fields do not affect its o eration. Features include "high operati economy," use for continuous recordi permanent records, etc. Small momenta

hanges in the subject's cardiac action appear immediately, thereby immediately making possible further investigation. Recorder of new electrocardiograph may be used in conjunction with other equipment for laboratory research. It provides an amplifier and recorder which will give a record between 1 cycle and 80 cycles per second at a sensitivity of 1 millivolt for 2 cm. total deflection; or a range from zero to 80 cycles for 60 millivolts for 2 cm. deflection. A high-speed writer can be supplied which will extend frequency range to approximately 200 cycles. Because of special damping circuit employed, excellent transient response is said to be secured. Although in the high-sensitivity connection, the amplifier is not a true d-c. amplifier, the phase correction is such that "perfect square-wave response" from 0.5 to 80 cycles is said to be realized with the one-millivolt sensitivity connection. —*Electro-Physical Laboratories, Inc., 45 West 18th Street, New York, N. Y.*

"Borescopes"

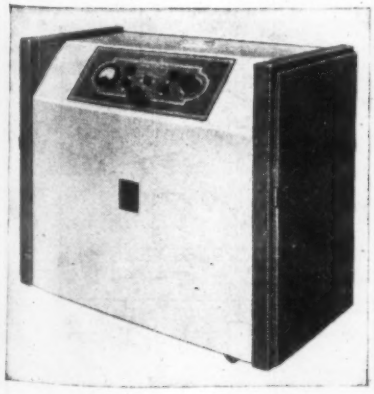
Originally designed for internal surface inspection of gun bores, "Polan Borescopes" are available to private industry, cover a diameter range from 13/16" to 9", and a



core length up to 30 feet. Makers have developed a complete line of these industrial telescopes, which are claimed to combine a highly corrected lens system, excellent interior illumination and rugged design. It is said that instruments do not strain the inspector's eyes when operated continuously, and require no special operator training. Borescopes are available in straight form, right-angle extension form (illustrated) and various special forms. In addition, various special attatchments have been developed.—*Polan Industries, 1407 Steward Ave., Huntington, W. Va.*

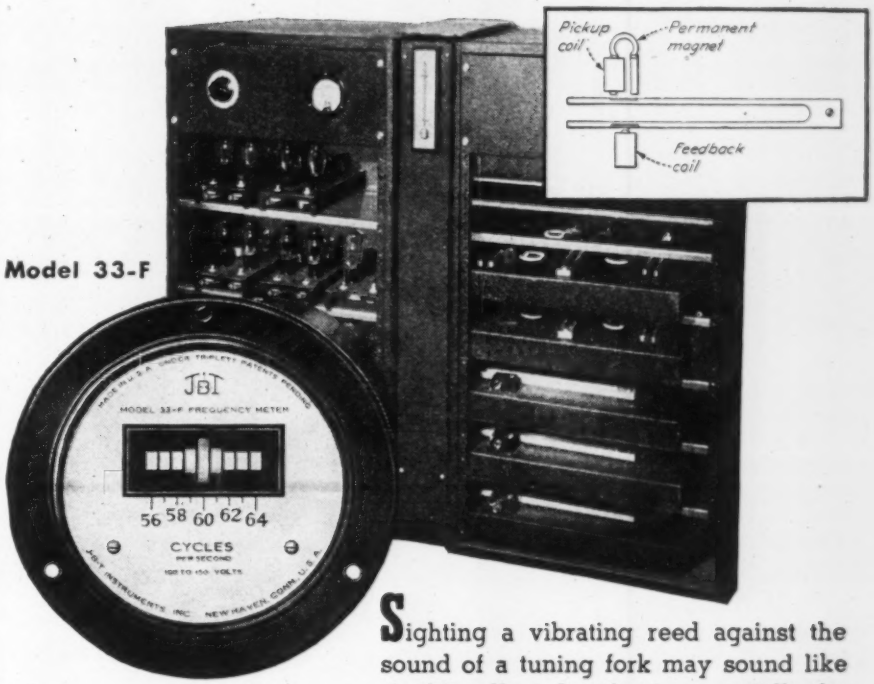
High-frequency Generators

New line of high-frequency generators with ratings of 1, 2, 5, 10 and 20 kw. in line with NEMA standards is announced for both induction and dielectric heating loads, is said to be a complete line. (Units of 50- to 200-kw. capacity can be supplied in addition to standard 1- to 20-kw. ratings.) Units are completely self-contained, require only electrical connection to a 60-cycle power



WIRED FOR SIGHT

Advanced Technique For Calibration of Reed Frequency Meters



Sighting a vibrating reed against the sound of a tuning fork may sound like double talk . . . but that is essentially the principle in the exacting process of J-B-T Frequency Meter calibration.

Tuning forks are the most dependable source of mono-chromatic vibration frequencies, so J-B-T engineers devised equipment, the *only* equipment of its kind, to translate the frequencies of temperature-controlled tuning forks into electronic impulses. These impulses are delivered to the stroboscopic and electronic calibration equipment at the assembly and inspection stations where they are used *visually* to prove the accuracy of every J-B-T Frequency Meter reed. And still not satisfied, J-B-T engineers check these master tuning forks daily against time signals from the Bureau of Standards.

The superiority of this equipment for frequency testing, exclusive with J-B-T, is recognized by authorities in the electrical industry and in the war effort. It is one of the reasons why J-B-T Meters can be guaranteed permanently accurate to ± 0.3% or better.

Send for illustrated bulletin VF-43, with supplements on 400 cycle meters, and the new compact 2½ inch meters.

•

For all 3½" instruments, black molded cases are now available to meet highest government standards and the mounting dimensions of ASA C 39.2—1944 and proposed JAN-I-6.

J-B-T

(Manufactured under Triplett Patents and/or Patents Pending)

J-B-T INSTRUMENTS, INC.

443 CHAPEL STREET • NEW HAVEN 8, CONNECTICUT 10-JBT-8

supply and have no external cooling or other auxiliaries. Primary voltage is 220 or 440 volts single-phase for ratings of 5 kw. or lower and 3-phase for 10 kw. and higher. Cabinet encloses oscillator, power supply, blower, and necessary switchgear. High-frequency section is completely shielded. Automatic timing control permits load cycle adjustment and automatic repetition. Terminals are provided for remote control. Use of air-cooled tubes in the standardized generators allows portability of the 2-, 5-, and 10-kw. units and increased portability of the 20-kw. unit. Tube-cooling air blower circulates air throughout entire equipment, augmenting factor of safety. Generators are available for frequencies of 450 kc., 5, 15 and 30 Mc. for ratings through 10 kw. and 450 kc., 2 and 10 Mc. for 20 kw. and higher. Time-delay switches are standard on all rectifiers. Step starters are used in 20-kw. and larger generators.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Dynamic Pressure Gaging Pick-up

New "Dynamic Pressure Gauge" is an electrical pick-up or gage head of the differential type, made in ranges of 0 to 1,000 lbs./in.^{2} and in intermediate ranges as low as 0 to 1 lb./in.^{2}. Low-pressure pick-ups have a frequency response of 0 to 200 cps. in higher ranges, dynamic characteristics are from 0 to 500 cps. Electrical characteristics: impedance bridge type for operation with 2000-cycle carrier equipment; input, 5 volts across gage bridge circuit; output, 7 millivolts. Temperature drift: 0.035% per degree Centigrade to +100° C. Style of electrical connections can be furnished as specified by user. Standard pressure connections are ⅛" NPS. Each gage head is furnished with static pressure calibration curve indicating diaphragm characteristics. Bodies of pick-up designed for high-pressure work are of stainless steel; pick-ups specifically designed for air-foil studies are of aluminum and furnished with leads rather than electrical connector. Associated power supply and amplifier equipment is also available from the manufacturer.—*Tinsley Instrument Co., 37 West Van Buren St., Chicago, Ill.*

Pneumatically-commanded Hydraulic Servo

New "Model 4000" hydraulic power unit has been specifically designed for use with air-operated automatic-control instruments. It substitutes an oil-hydraulic cylinder for the usual spring-opposed diaphragm while the rest of the controller remains the same and operates in the usual manner. The result is a pneumatic-hydraulic automatic

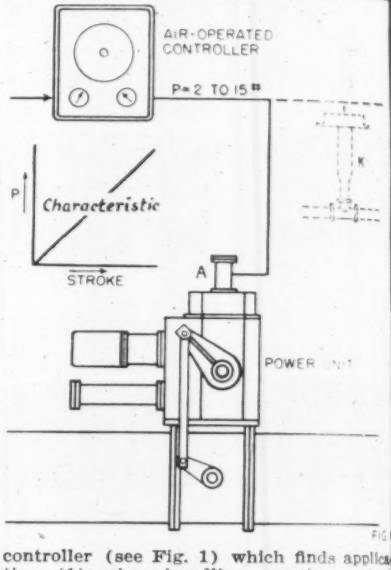


FIG.

controller (see Fig. 1) which finds application (1) when handling erratic or shock loads where it is necessary to have not only instantaneous application of power but also self-locking action which can only be had with an incompressible medium like oil; (2) when handling heavy loads; (3) when double-acting operation of the servo-motor is necessary to provide braking action; (4) when exceptionally long strokes are required; (5) when these power requirements are supplemental to those of other final elements, such as K in Fig. 1, for which air operation is desired without change. *Operation* (see Fig. 2): Air loading pressure from the control instrument is applied to bellows A. Bellows movement acting through jet-pipe relay B sets hydraulic piston E in motion. Follow-up cam C, operated from piston E, controls action of jet-pipe relay so that position of piston is always a function of loading pressure. When not otherwise specified, cylinder produces a stroke directly proportional to loading pressure. *Description*

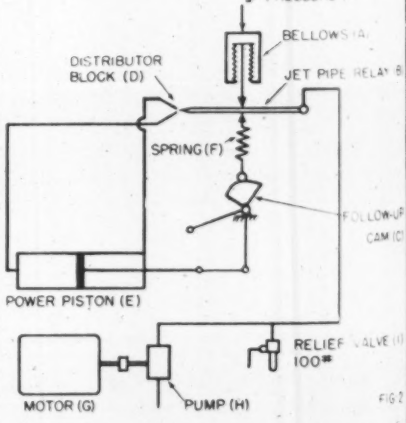


FIG 2

Now—Air Operated Collet Chuck Relieves Second Operation Work on Screw Machines

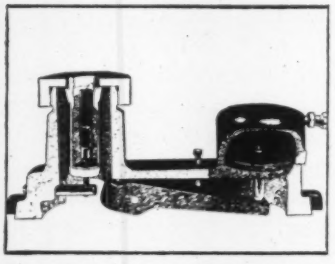
Work formerly requiring automatic or hand screw machines can now be done at much less cost through the combination of this new air chuck and any drill press. The Redmer Air Chuck is a collet air chuck using standard Brown & Sharpe type screw machine collets. The collet remains stationary, the opening and closing controlled by a sleeve action.

By using a collet as the chucking means, slight variations in the diameter of the work as frequently experienced with automatic and hand screw machine products can be permitted without sacrificing accuracy or concentricity. Thus accomplishing an important saving in time and cost.

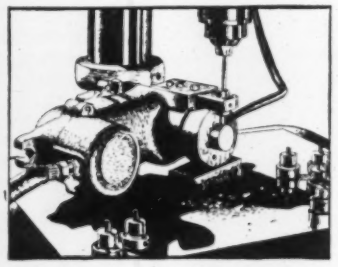
The air chuck is an ideal tool for holding parts for drilling, milling, slotting, burring, chamfering, boring, counterboring, tapping, threading, reaming and other work where the machine operation should be concentric with the chucking surface. It is adaptable to many different jobs merely by changing collet and stop. This results in saving of valuable production metals and materials. The chuck will take any type work whether round, hex, square or rectangular, and permits full efficiency of the operator, as it is operated by a foot operated valve thus leaving hands free to load and unload—reducing fatigue and cutting unproductive time to a minimum.

Wrigley's Spearmint Gum, too, is a help on the job. For chewing gum helps relieve dry throat, and helps ease fatigue brought on by the strain of work. And at the same time you are chewing and getting the benefits of swell tasting Wrigley's Spearmint, both hands are free and you need not take a "time out." The Army and Navy have recognized these benefits and are now shipping overseas *only,* all of the limited production of Wrigley's Spearmint. When Wrigley's Spearmint can again be produced in sufficient quantity for all, the valuable benefits of Wrigley's Spearmint Gum now being proven on the battlefield will apply to industry here at home.

You can get complete information from Redmer Air Devices Corp., 601 West Washington Blvd., Chicago 6, Ill.



An air operated collet holding fixture for precision chucking or machine tools



Chuck can be mounted on angle for angle milling job

Y-151

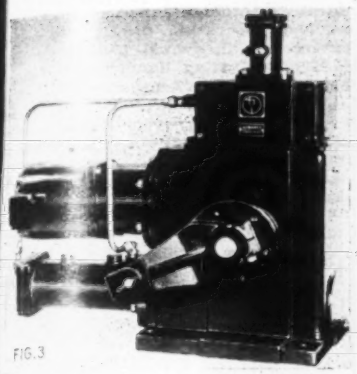
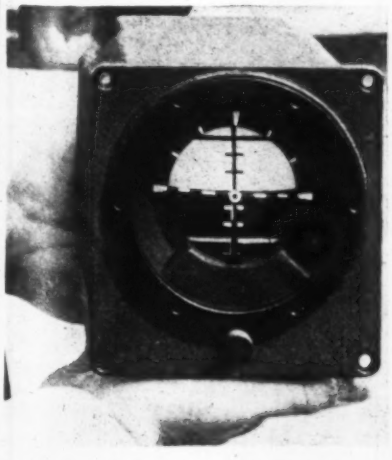


FIG. 3

Motor, pump, relay and hydraulic piston are all assembled in a completely self-contained self-lubricated unit as shown in Fig. 3 (so that no piping or expert adjustment is needed in the field). Power developed by piston is transmitted to valve lever, or other mechanism to be operated, by means of a crank arrangement. Among claimed advantages are: (1) piston rod is not exposed to dirty or corrosive atmospheres; (2) available force can be multiplied by taking advantage of knee action of crank, for handling valves which have a tendency to stick near closed position or require extra force to close against high pressure; (3) crank action obviates trouble due to bad characteristics of butterfly valves, particularly near closed position. *Some performance characteristics*: A change in loading pressure of 1 oz. and a bellows movement of 0.0066" will start piston in motion. As this represents a displacement of air of only 0.0016 in.^{3}, air consumption of new power unit is practically nothing and unit can be operated from any pneumatic prime relay without the complication of additional relays. At no load, time required for complete stroke of crank arm is 12 seconds; at 50% of stalling load, time is 24 seconds. Stalling torque is 4000 in.-lbs. and no harm can come to unit if it is stalled. Maximum pull on connecting rod is 1550 lbs.—*Askania Regulator Co., 1603 S. Michigan Ave., Chicago 16, Ill.*

Attitude Gyro

New "Attitude Gyro" is a new type flight instrument capable of providing the pilot with precise *attitude* indications throughout 360 degrees of roll and pitch. For the first time in the history of aviation, it is said, the pilot is provided with a visual indication of the position of his aircraft with reference to the earth's surface throughout all possible attitudes through which his airplane can be maneuvered. New Attitude Gyro is adaptable to all types of airplanes and is particularly valuable to those aircraft whose mission requires extensive and complicated aerobatics. (In the past, it has



Hickok INTERNAL PIVOT METER

ALL HICKOK D. C. Panel Mounting Meters have the improved internal pivot construction. Both pivots are removable. This HICKOK internal pivot movement is also *shock-proof*. It meets the American War Standard Specification C39.3-1943. It also exceeds the requirements of Paragraph F-23 of Specification C39.2-1944. Jewels are mounted in a solid metal core and the pivots are mounted on the inside of the moving coil. Consequently, the pivot and jewel adjustments are permanent. The assembly is thinner than most designs, permitting the use of a more shallow case. Write for new catalog No. 23.

THE HICKOK ELECTRICAL INSTRUMENT COMPANY

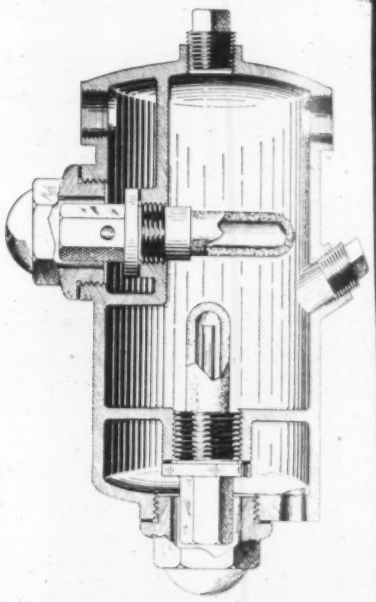
10519 DUPONT AVENUE, CLEVELAND, OHIO

THE STANDARD OF QUALITY FOR A THIRD OF A CENTURY

been impractical to perform all aerobatic maneuvers without visual reference to the earth's surface.) As in other gyro flight instruments, a gyroscope is the heart of the new attitude indicator. Electrically propelled around a vertical axis, the gyro provides a fixed reference pattern around which the plane may be maneuvered in any direction —an entirely new feature. Reference pattern is marked on surface of this stabilized sphere with luminescent paint and is visible to pilot through a masked opening in front of instrument case. Indicating sphere is divided into hemispheres by painting upper half white luminescent and lower half black. Latitude lines are inscribed with short 10° marks between. Vertical meridian line gives roll angle indication with reference to a fixed index on mask around sphere. A lateral lubber line, marked in alternate black and white sections, stretches across center of mask opening and provides basic pitch index. The only operating knob or adjustment required by the pilot is that for the "target," a small circle which adjusts up and down to compensate for change in trim of the airplane for level flight. — *Sperry Corp., 50 Rockefeller Plaza, New York City.*

Air Cleaner for Instruments

New series of "Liqui-jectors" is said to afford a new measure of protection for pneumatic instruments through "a revolutionary new principle for automatically and continuously removing condensate (droplets, slugs, or mist) from compressed air and gas lines." New "Liqui-jectors" are adaptable to air and gas lines up to 1¼" pipe size and normal line pressures. No moving parts are involved, and no cocks, traps or shutoffs are required in the drain line (which is open to the atmosphere). Action is entirely automatic and continuous through two porous ceramic tubes—one inherently water-repellent, the other water-permeable but at impervious. Operating principle is said be a recently-discovered metho for aut matically separating liquid and gas phas by virtue of surface tension of liquid. Co pressed air entering "Liqui-jector" pass through first (water-repellent) tube, whe it is stripped of moisture. Action is coale cence of droplets on surface of tube coarse ceramic material with an averag of 50,000 pore openings per square inc



each so small that pressure drop acros tube is insufficient to permit water passag against resisting diaphragm-action of it surface tension. Coalesced moisture drop to bottom of unit where it passes through second tube (without loss of air) to outside atmosphere. This second tube is constructed of micro-porous porcelain, with an average of 720 million pore openings per square inch and, being constantly wet by its wick action, constitutes a perfect air seal up to rated working pressure of unit. (This rated pressure may be manipulated to user specification.) Illustrated is smallest unit, "Model A-150-1," which accommodates lines up to ⅜" pipe size with line pressure up to 100 lbs./in.². — *Selas Corp. of America, Erie Ave. & D St., Philadelphia 34, Penna.*

Aircraft Direction-indicating Compass

New "Type 2221 Direct Reading Magnetic Direction Indicator Compass" is said to be particularly adapted to passenger and cargo planes as well as to private aircraft. Azimuth pointer rotates in front of a fixed

The HATHAWAY Type OA-2 OSCILLOGRAPH GALVANOMETER employs a magnetic circuit of unique design, combining for the first time, high sensitivity with small size. Universal mounting is ⅝-inch wide, allowing Type OA-2's to be mounted side by side on ¾-inch centers.

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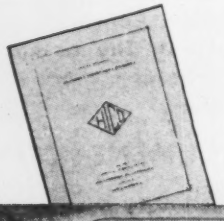

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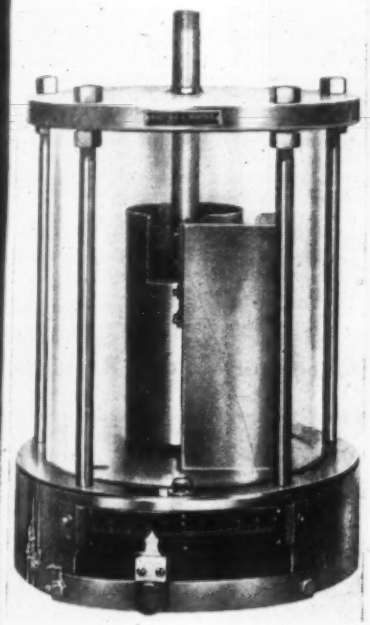
Flow Bifurcator

New flow splitter, called "Micro-Rotaweir," is designed to accurately divide a liquid flow into two streams. Proportions may be varied by adjusting an outside lever-and-pointer to the percentage desired (indicated on external scale). *Operation:* Inlet pipe (top) discharges into a receiving chamber which has a rectangular weir as an overflow. A vertical knife edge, set against external edge of weir, divides stream into two parts as it flows over lip of weir. One stream flows into a closed compartment with bottom outlet; the other spills into area surrounding receiving chamber and discharges also from bottom.



Receiving chamber is connected through a stuffing box at bottom to an external lever by means of which the weir may be rotated to any position with respect to the flow-dividing knife edge. Micro-Rotaweir may be obtained with fittings in all metals. Shell may be metal or Pyrex glass (as in illustration). For high melting fluids, metal shell may be lagged and steam-heating coils placed inside. Micro-Rotaweir will handle flows from 30 to 900 g.p.h. Sizes up to 15,000 g.p.h. are also contemplated. *Applications:* Proportioning product to reflux on small pilot plant stills; dividing liquid flow to twin absorbing units, cooling towers or other reactance vessels operating in parallel; flow splitting for liquid blending and flows to storage tanks.—*Fischer & Porter Co., 923 County Line Road, Hatboro, Penna.*

Wire-wound Resistor

New design of "Type 58" wire-wound rheostat or voltage-dividing resistor is said to be fully capable of coping with extreme vibration and mechanical abuse. Metal strap on shaft face provides for two-position locating pin which cannot break or tear off. Also, strap grounds metal cover which is

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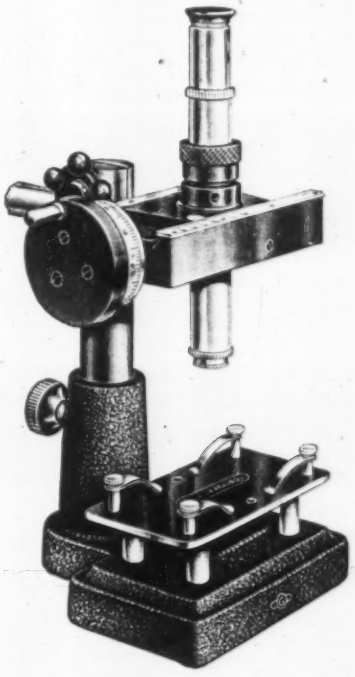

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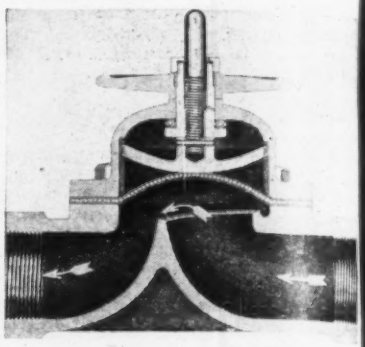
manual pilot valve, from the needle valve of automatic devices, etc. In many service these valves replace more expensive valves and, in addition to initial-cost savings, there are considerable savings in maintenance. New valves are available in sizes from ¼ to 6" pipe sizes, with screwed or flanged ends, in various body and diaphragm materials, with linings such as glass, rubber or lead: manufacturer has compiled a list



of more than 100 acids, alkalies, abrasive suspended solids, etc., for each of which the recommended materials and linings are "practically indestructible." Diaphragm is always of a synthetic composition selected for the particular service. In general, line pressure limit is 150 lbs./in.² and temperature limit is 150°F. but higher limits are allowed in some cases. Valves may be installed in horizontal or vertical position above or below ground. Diaphragm can be replaced without removing valve from line. Valve is especially desirable for on-or-off service (absolutely tight shut-off unaffected by solids trapped on seat) but can be used for throttling service within certain limitations. Since no fluid comes in contact with working parts, mechanism cannot freeze for outdoor service.—*McAlear Mfg. Co., 1901 Western Ave., Chicago 8, Ill.*

Generator Voltage Regulator

New "Synchrostat" voltage regulator is designed for use with a-c. generators using direct-connected, belted or motor-driven exciters, 50-60 cycles standard. It consists of a basic metal-enclosed unit adaptable for regular generator switchboard mounting and for mounuting-on-top-of-the-generator in "packaged" power units. Voltage regulation is ± 2%; regulator quickly responding to load changes to restore generator voltage to normal. New regulator is of the synchronous-contact type: vibrating tungsten contacts of regulator relay operate every half-cycle of the a-c. wave to insert and to remove a resistance in shunt field circuit of generator exciter. Regulating action is ob-

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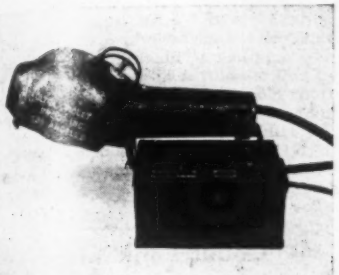

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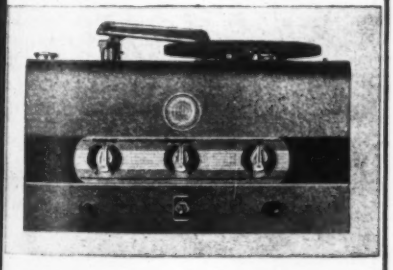

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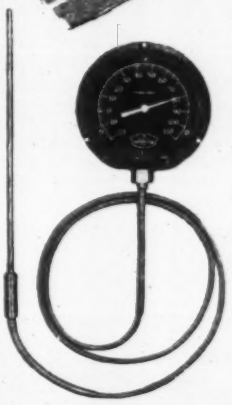

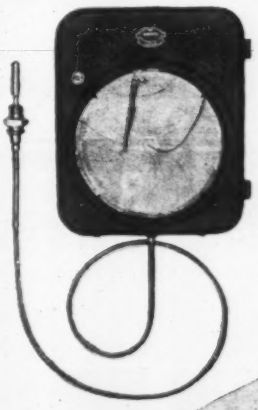

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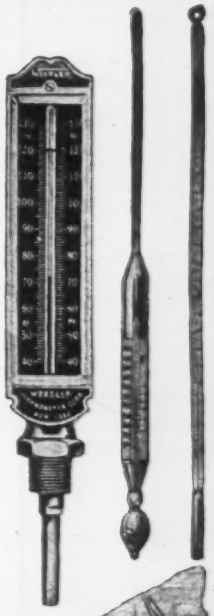

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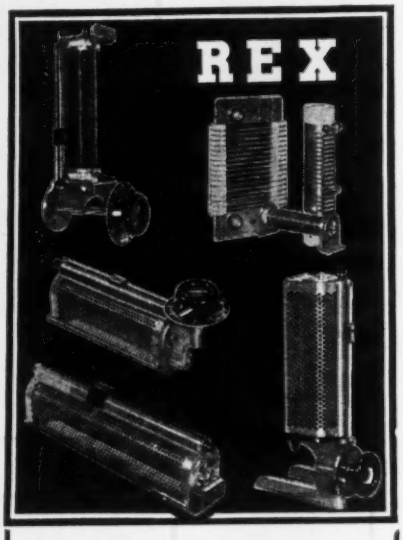

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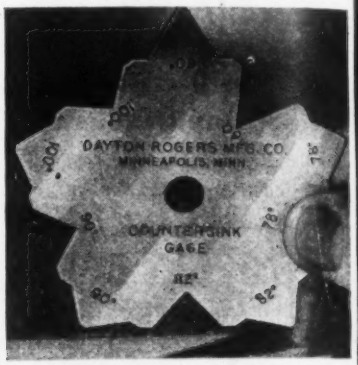

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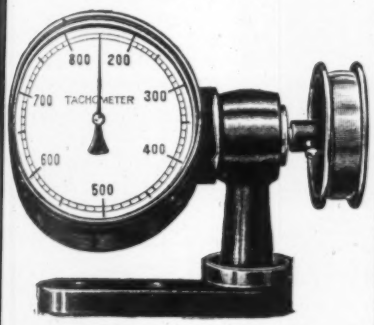

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Electrical Instrument Accuracy

Continued from page 600

ments for the measurement of current and voltage in radio applications justifies brief mention of their characteristics.

Rectifier-type instruments usually consist of a small full-wave type rectifier, the d-c. output of which is connected to a permanent-magnet moving-coil type of element. These instruments are generally used on frequencies through the audio range, whereas the thermocouple types may be used for the measurements at audio or radio frequencies.

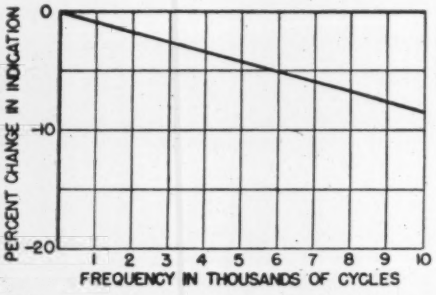

Fig. 7. Curve showing full-scale frequency errors of a typical 15-volt rectifier type instrument (1900 ohms per volt).

No general statement on temperature errors of rectifiers can be made, since their temperature characteristics depend on instrument design requirements. Under unfavorable conditions this type of error may be appreciable.

Since rectifier-type instruments respond to average values of alternating current, if the instrument is calibrated on a sine wave, the wave-form errors will vary with the change in the ratio of the average and effective values of the alternating current. On distorted waves the error may be large.

Frequency errors in correctly-designed rectifier-type instruments are not usually excessive over the audio-frequency range. At the upper end of this range capacitance effects between rectifier plates begin to affect the accuracy, however. The curve in Fig. shows frequency characteristics typical of rectifier-type instruments.

In thermocouple-type instruments the temperature errors in general do not exceed those specified under switchboard and portable instruments as previously discussed. Wave-form errors are negligible.

Errors in thermocouple instruments themselves at the higher frequencies are principally due to the "skin effect" in the heater wire. With an increase in frequency the current tends to crowd to the outside surface of the heater wire, raising the temperature of the couple and increasing the pointer deflection. The exact amount of error again depends upon the design of the thermocouple. A curve showing errors in a typical small panel thermocouple-type instrument is shown in Fig. 8.

The application of thermocouple instruments for high-frequency measurements is a highly specialized art and in general should be undertaken only by engineers trained in radio or high-frequency technique. The physical location of the instrument is of particular importance, as well as the potential above ground at which the instrument operates. If proper consideration is not given to factors such as these, not only inaccuracies in the instrument may result but the instrument element itself may be destroyed by leakage currents.

Thermocouple instruments are not as sturdy as rectifier types, particularly under overload, but they are more accurate when properly applied for radio-frequency measurements.

HANDLING OF INSTRUMENTS

Instruments in general are required to operate on small values of power. As a result, fine bearings and small

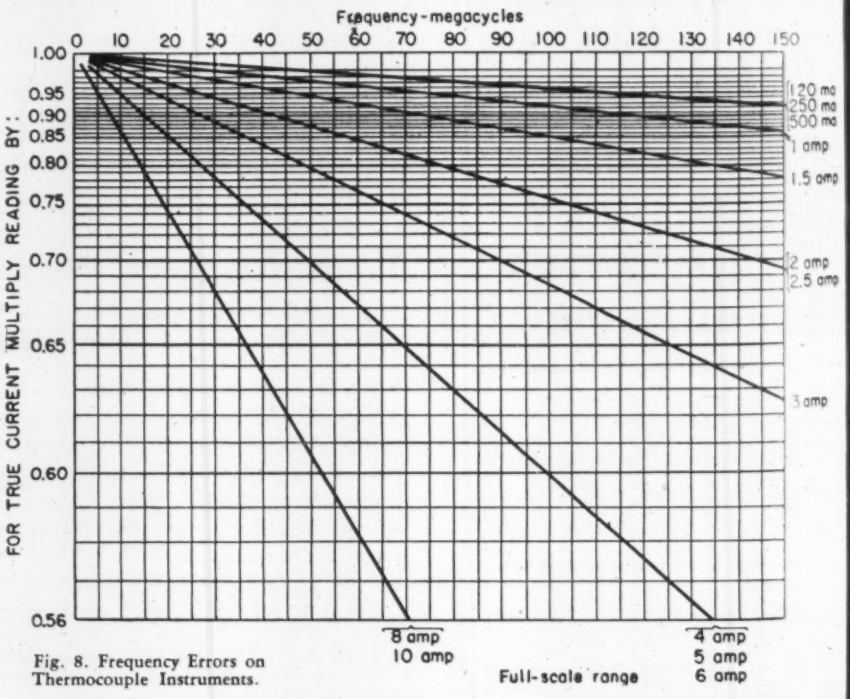

Fig. 8. Frequency Errors on Thermocouple Instruments.

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With the large number of instruments being used in fighting equipment, it is doubly important that all precautions be taken so that the devices will arrive at the front in the best possible condition and thus be more effective in destroying the enemy.

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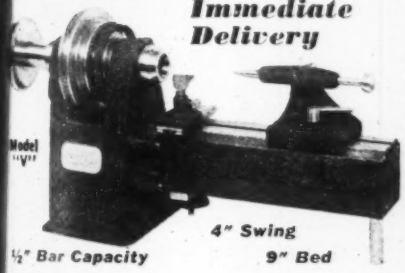

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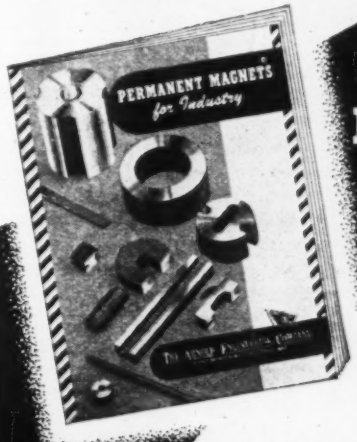

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Instruments in the War Effort

Sergeant Develops Automatic Wire-inspection Instrument

TONS of field wire, that might otherwise be discarded, are being salvaged because of the ingenuity of Staff Sergeant Pasqual L. Wamil, Santa Barbara, Calif., assigned to a Signal Depot Company at a U. S. Army invasion base in Southern England, according to reports received in the Office of the Chief Signal Officer.

Sergeant Wamil, a native of Sanchez Mira, Gagayan, Philippine Islands, has developed an automatic continuous tester which detects defects in the insulation of wire used for field telephones. Officers in charge of his Signal Corps section saw that it would be impossible to examine for defective insulation every inch of wire returned for salvage. Couldn't some sort of robot be constructed that would indicate when there was a rupture in the insulation? S/Sgt. Wamil had attended Stanford U and had worked as an electrician at the Mare Island Navy Yard; he believed that it could be done. Using only scrap material, he constructed a working model consisting of two parts—a control box which by means of a ringing bell signalled any defect in the insulation; and a series of electrodes in the form of pipes through which the tested wire passed while being wound onto reels. Power-operated spools coiled the wire after it passed through the pipes. It became a relatively simple matter to find the break, however minute.

To increase the daily mileage capacity of the automatic tester, Sgt. Wamil employed four electrodes instead of one, plugged in separately to the control box. On the front panel of the control box he mounted four simple hand switches which, when closed, energized the electrodes. Above each switch was attached a small wooden tab hinged at the bottom, held upright magnetically and dropping when its circuit was opened by a relay actuated by the fault-detection and bell-ringing circuit. The purpose of these annunciator tabs was to show which of the four wires being tested had a broken insulation. This in turn made it possible to keep in operation, while one defective wire was being repaired, any or all of the remaining spools.

Phase Difference Microscopy

INCREASED visibility through the microscope was demonstrated at the Cleveland meetings of the American Association for the Advancement of Science in September. The report was made by Dr. A. H. Bennett, Director of Research and Dr. O. W. Richards, Research Biologist, of the Spencer Lens Co. The method of obtaining the increased visibility, known as Phase Difference Microscopy, was described some years ago, but equipment to make it practical has just been devised by men in the Research Division of Spencer Lens Co. The Spencer contribution extends the method to the general case, the discovery that absorption may be as important or more important than retardation, the preparation and use of a wide range of phase disks of both

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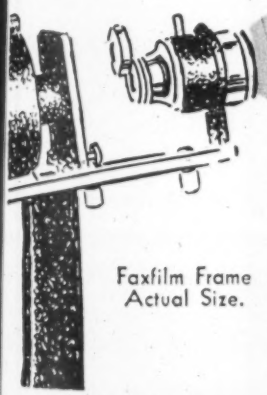

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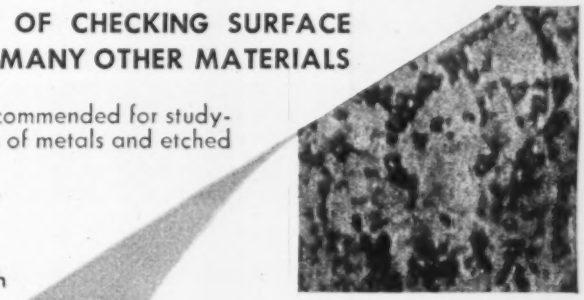

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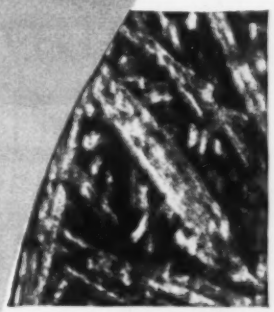

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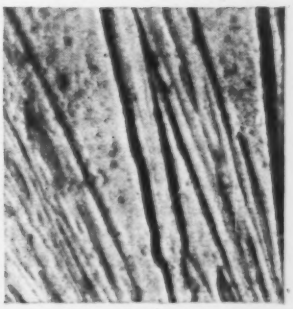

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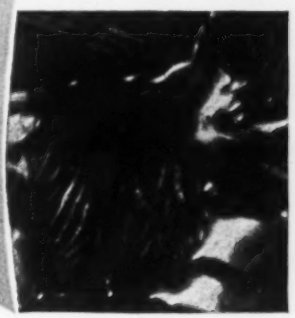

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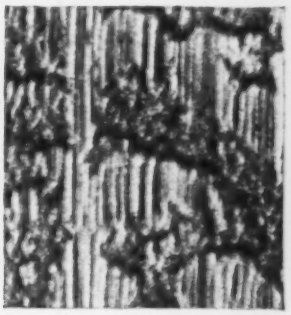

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Tests Prove Copper-oxide Rectifiers Can Stand Higher Ambient Temperatures

To the Editor of *Instruments*:

Today, copper-oxide rectifiers are being used in many Army and Navy applications where ambient temperatures are encountered that are much higher than usually found in industry. Normally such rectifiers are rated on the basis of 35°C. ambient. Operation where the ambient temperature will rise perhaps 5°C. above this value for short periods is not harmful to the rectifier.

Where prevailing ambients exceed 35°C., a standard method for derating copper oxide rectifiers is used. This procedure reduces voltage rating of the unit 10% for each 5°C. increase in ambient above 35°C. Thus for 50°C. ambient, common in Navy requirements, voltage rating is dropped to 70% of its standard 35°C. value. No change is made in the current rating.

A recent test run demonstrated the conservatism of these ratings. Two standard rectox units taken from the production lines were set up in a hot chamber where ambient temperature was held at 50°C. One unit was loaded at normal 35° rating —1 ampere at 9 volts d.c. The other was loaded at 50°C. rating, applying the derating factor of 70% already mentioned. The load on this unit was 1 ampere at 6.3 volts d.c.

Both units were operated continuously for 3000 hours with complete success. The fact that the derated unit did so is not cause for surprise. However, the other unit (not derated) also operated in this ambient for 3000 hours. The conservatism of the standard method for derating rectox units operating at high ambients is well shown by this test. The test also proves that the 35°C. rating includes a comfortable safety factor.

I. R. SMITH,
Control Engineer, Westinghouse E. & M. Co.
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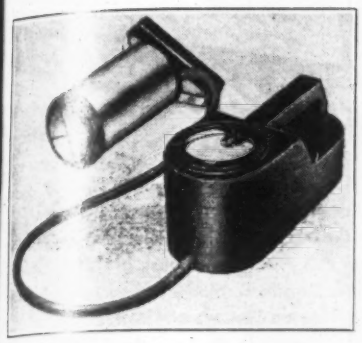

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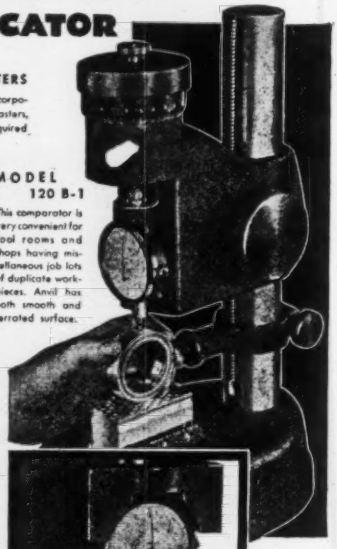

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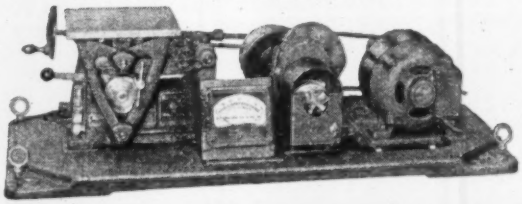

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METALWORK — TECHNOLOGY AND PRACTICE. By OSWALD A. LUDWIG. McKnight & McKnight, Bloomington, Ill., 1943. Cloth, 7¾ × 10½ inches. Price $4.00.

This book is designed as a survey course for beginners in the metalworking industry to provide a background for almost any type of metalwork and instruct generally in most of the jobs in almost any kind of metalworking shop. The book is prefaced with an outline of the manner in which the book should be used and a short description of the various types of metalworking jobs such as airplane mechanic, annealer, apprentice, assembler, auto mechanic, bench hand, blacksmith, etc. It is developed, generally, from the standpoint of types of operation with the following part headings: Planning the Job, Bench Work and Power Saw, Getting Acquainted with Metals, Care of Equipment, Drill Press Work, Threads, Dies, Taps, Fitting and Assembling, Work with Sheet Metal, Heating Metal, Tool Sharpening, Finishing and Inspecting, Machine Tools.

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—R. A. BOWMAN, *Major, Ord. Dept., In Charge of Pittsburgh District Gage Laboratory, A.S.F.*

MECHANISM AND THE KINEMATICS OF MACHINES. By W. STEEDS. Longmans, Green and Co., London, New York and Toronto, 1940. Cloth, 5¾ × 8¾ inches, xii + 319 pages. Price 5.00.

After first presenting a brief résumé of the analytic treatment of the motion of a point, the author deals with the motion of a solid body. From a consideration of the degrees of freedom and the proper constraints of a body, means for obtaining desired motions without the undesired components such as back lash, etc., are described. Geometric or kinematic principles are used extensively in obtaining various motions and actions by mechanisms without regard to the forces that produce the motions or arise from them. To a great extent the parts of the machine are represented by geometric lines, so that only the skeleton of the machine is considered.

Motions by means of links and joints, gears, belts, chains, cams, ratchets, escapements, etc., are treated. The designs of the proper shapes of gear teeth and cams are given in considerable detail.

In general, the principles set forth in this book apply to both small mechanisms, as used in instruments, and to mechanisms where large forces are encountered. There are sketches with explanations of many different types of mechanisms. Numerical examples to a large extent, are presented by means of problems and answers.

—C. K. STROBEL, *Assistant Director, Robertshaw Research Laboratory, Pittsburgh, Pa.*

ELECTRON OPTICS. By PAUL HATSCHEK (translated from the German by Arthur Palme). American Photographic Publishing Co., Boston, 1944. Cloth, 5 × 8 inches, 161 pages. Price $3.00.

The elementary electronic devices are presented in simple language, completely without mathematics beyond arithmetic. The vacuum tubes of vintage 1936 are described in terms suited to readers having no previous acquaintance with the subject, mostly by the use of analogies; how automobiles swerve when driven from smooth roads to rough and the like. The book is written with admirable clarity, but it is not as interesting as an article in *Life* or in the *Post* on the same subject—for example on television—and steers a course somewhat closer to a textbook style. On the other hand, it does not have the "meat" in it that a textbook would have. There are only a few circuit diagrams—in connection with amplifiers and voltage multipliers—and no characteristic curves. A few pages have been added by the translator mentioning modern electron microscopes and diffraction.

—C. S. BARRETT, *Carnegie Institute of Technology, Pittsburgh.*

THE VISMETER. By CARL D. MILLER. The Andover Press, Andover, Mass. 1944. Paper, 6x9 inches, 24 pages. Price $1.00.

Under the title, there is printed the following: "A Scientific and Educational Brochure." This sub-title is accurate, for Dr. Miller does more than merely describe his invention in commercial catalog style. As a matter of fact, there is no photograph of the Vismeter—not even a diagrammatic sketch of this instrument: only a purely schematic diagram in blackboard style. This simple drawing closely resembles the cross-section of a bearing and its journal, with exaggerated oil-space, which is drawn on the blackboard by lecturers on lubrication theory.

And a "lecture" is what this brochure seems to be—an interesting and well-developed lecture on the theory and realization of CONTINUOUS-FLOW VISCOSIMETRY—which Dr. Miller asserts in his Foreword to be a new field of physical measurement opened up by the Vismeter. To many *Instruments* readers in the processing industries, who suffer from the inconvenience (and worse disadvantages) of taking a sample and waiting for the result of the viscosity measurement, there will be a fascination in the possibility of continuous *in situ* sampling and measurement, with indications and records on a centralized board, and even the possibility of effective auto-

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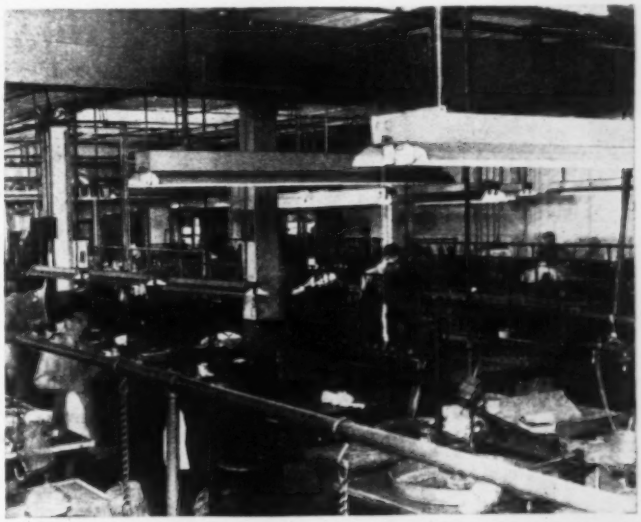

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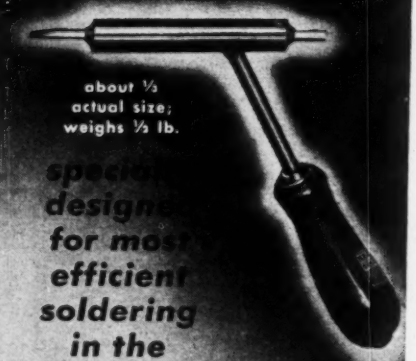

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matic control. I must repeat, however, that this brochure does not contain any industrial instrumentation details. (If it did it would not be reviewed under "Books" but under "Manufacturers' Literature.")

Dr. Miller's exposition of the underlying principles is original—perhaps "unorthodox" to a mathematical physicist or to a physical chemist—but the fact that his first Venturi meter patent was filed twenty-two years ago is an adequate assurance that this text is not the hasty product of a sudden "inspiration." On the contrary, it has the earmarks of painstaking preparation as well as particularistic presentation.—M. F. Behar

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PRINCIPLES AND PRACTICE OF FLOW METER ENGINEERING. By L. K. SPINK. Sixth edition. The Foxboro Company, Foxboro, Mass. Cloth, 5½ × 8 inches, viii + 200 pages. Price $3.00.

"This handbook, widely accepted as a standard text and guide, has just appeared in a new and enlarged edition, the sixth since the book was first published in 1930. New and advanced phases of the subject are covered for the first time. The author, L. K. Spink, is a member of the working committee which developed the latest AGA orifice meter tables, a member of the ASME Fluid Meter Research Committee, and of the joint AGA and ASME Pulsation Research Committee. As an engineer who has devoted many years to the study of flow measurement, he is extraordinarily qualified to handle the subject.

"The book is illustrated with photographs, diagrams and curves, and contains all the tables and formulae needed for any ordinary liquid or gas flow computation. In the Liquid Section, some of the features are methods for determining compressibility factors of liquids at temperatures near the critical, a new and more accurate method of correlating temperature expansion data on petroleum oils, a quick method of correcting for tap locations, and a short-cut method of correcting for viscosity.

"The Gas Section suggests several methods of correcting for viscosity effects. Theoretical discussion, as well as working equations and tables for moisture and supercompressibility, are presented. A new and simple type of intermediate pressure device which eliminates the by-passing of gas is described. The latest findings on the measurement of pulsating gas flows are covered." [Publisher's announcement.]

AIRCRAFT RADIO AND ELECTRICAL EQUIPMENT. By HOWARD K. MORGAN. Pitman Publishing Corp., New York, 1939. Cloth, 6 × 9 inches, x + 384 pages. Price $4.50.

"This book was written to provide clear understanding of the operation and use of present-day and future aircraft radio and electrical equipment.

"The author holds a B.S. Degree in Electrical Engineering from the University of California and has been affiliated with the Communications Division of Transcontinental and Western Air, Inc., since 1932. His first task with the airline was to aid in development of receivers for ground stations. The equipment conceived and placed into use in that early day of the air transport business, is still standard and in service.

"Realizing that everyone interested in flying is also concerned with such vital aids as the radio and electrical equipment of planes and airways, Mr. Morgan has designed his text to provide simple explanations of all phases of the subject. It is written not for those trained in electrical science, but for the ordinary user of the apparatus with which it deals. It explains fully the basic principles and theories on which aviation radio and electrical apparatus operates, explains them so simply and clearly that anyone in the least mechanically minded can understand and follow. It describes modern equipment in detail, with diagrams accompanying, and prepares the reader for the further developments which are now in process or are to be expected."
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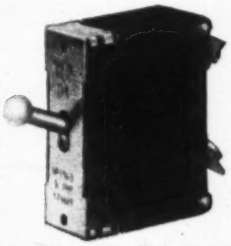

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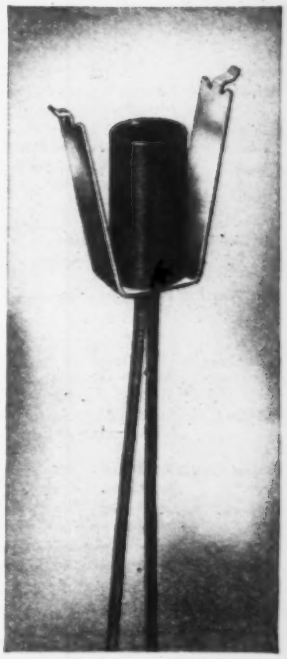

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INSTRUMENT SOCIETIES CALENDAR

City, Society and Secretary			Date	Place	Subject	Speaker
Atlanta	Georgia Society for Measurement & Control	Roger W. Allen, 376 Nelson St., S.W., Atlanta				
Baltimore	Baltimore Industrial Instrumentation Society	C. B. Willnecker, 6732 Danville Ave., Dundalk, Md.				
Chicago	Chicago Society for Measurement & Control	A. J. Butler, 2626 W. 31st Blvd., Chicago	Nov. 6[B] Dec. 4[B]	Merchants' & Mfrs' Club, 237 M. Mart Merchants' & Mfrs' Club, 237 M. Mart	Pneumatic Null Balance Systems Television & Other Future Aspects of Electronics	Coleman Moore, President Moore Products Co. Commander Wm. C. Eddy U. S. Navy
Cleveland	Cleveland Instrumentation Society	W. A. Stubblefield, 2085 W. 104th St., Cleveland 2	Oct. 25[B]	Cleveland Engineering Society	Ratio-type Electrical Thermometers	L. D. Montgomery, Research Engr., Hickok Elec. Instr.
Fort Worth	Fort Worth Electronics Club	Ralph Ely, 1116 E. Arlington, Fort Worth, Tex.	Nov. 16[A] Dec. 21[A]	Texas Hotel Texas Hotel	Stroboscopic Observation Telemetering	Wendell C. Fowler, Sangamo Electric Co. H. R. McKenzie, Texas Electric Service Co.
Gulf Coast	Gulf Coast Instrument Maintenance Men's Ass'n	T. H. Pierson, 3030 Roberts St., Beaumont, Tex.				
Hartford	Hartford Society for Measurement & Control	S. J. Zelle, Whitney Chain & Mfg Co., Box 1410, Hartford, Conn.				
Kansas City	KC Industrial Instrumentation Society	Gordon H. Burke, 1527 Broadway, Kansas City, Mo.	Oct. 31[B]	Bluebird Cafeteria	The Rotameter and Its Secrets	Kermit Fischer, President Fischer & Porter Co.
Newark	New Jersey Society for Measurement & Control	Robt. H. Gray, 1 Whippoorwill Way, Mountainside, N. J.	Nov. 14[B]	N. Y. City—joint meeting—see N. Y. Society announcement below)		
New York	New York Society for Measurement & Control	H. R. Kalbfleisch, 144-35 No. Blvd., Flushing, N. Y.	Oct. 31[B] Nov. 14[B]	Men's Faculty Club Columbia Univ., 400 W. 117th St.	Cathode-ray Tubes and Oscillographs Pyrometry in Steel Industry	P. J. Christaldi, Allen B. DuMont Laboratories Dr. R. B. Sosman, U. S. Steel Corp.
N. Indiana	Northern Indiana Soc. Measurement & Control	R. W. Schreiner, 4 Waltham St. Calumet City, Illinois				
Philadelphia	Philadelphia Society for Instrumentation	J. E. Gambrill, 1317 Spruce St.	Nov. 15[B] Dec. 20[B]	Engineers Club Engineers Club	Electronic Design Applied to Automatic Control Manometer Applications in Industry	Dr. T. A. Cohen, Wheelco Instrument Co. A. A. Heiduk, Meriam Instrument Co.
Pittsburgh	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh.	Oct. 23[B]	Roosevelt Hotel	Flow Measurement Engineering	L. K. Spink, Foxboro Co.
St. Louis	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.				
Toronto	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co., Toronto	Oct. 26[B] Nov. 16[B]	(To be announced) (To be announced)	Oscillography (To be announced)	P. Cavanaugh, Allen B. DuMont Laboratories Coleman Moore, President Moore Products Co.
Washington	Instruments Society of Washington	W. A. Wildhack, 328 N. Oxford St., Arlington, Va.				
Wyandotte	Instrument Society of Wayne County	John MacPherson, RFD No. 1, Wyandotte, Mich.	Oct. 23[B]	West Mound Church near Telegraph	Combustion Instruments	R. A. Wright, Hays Corp.

[A]Meeting at 7:30, no dinner. [B]Dinner at 6:30, meeting at 8. [C]Dinner at 7, meeting at 8. [D]Meeting at 8, no dinner.

CHICAGO

For our September meeting the speaker was Mr. C. H. Gibbons of the Baldwin-Southwark Division of Baldwin Locomotive Works. The September meeting was our first of the 1944-45 Technical Session and Mr. Gibbons gave an interesting and instructive paper on "Strain Gages—Uses and Applications." Following the paper there was a very interesting discussion. Mr. Gibbons exhibited a very intense knowledge of his subject and the unbiased character of his presentation and his subsequent answers to all the questions were greatly appreciated. —GORDON THOMASSON

KANSAS CITY

During the business session of our September 26th meeting the Nominating Committee was elected: L. A. Mears of Sullivan Mears Co., H. B. Manley of J. F. Pritchard Co., and E. A. Thompson of Minneapolis-Honeywell Regulator Co. They will submit their nominees for Society officers at our next meeting on October 31.

Ed Thompson of Minneapolis-Honeywell presented a basic lecture on thermocouples. Ed ably explained from Seebeck's discovery to Peltier's and Thomson's effects as to just what makes a thermocouple percolate. Our "Quiz Kids," H. B. Manley of J. F. Pritchard Co., W. L. Middletone of Fluor Corp., O. L. Boutros of Boutros Instrument Co., and K. R. Boob of North American Aviation, didn't take a back seat to Messrs. Seebeck, Peltier and Thomson when it came to answering questions on thermocouples. They couldn't be stumped.

Lester Johnson of the Sinclair Refining Co. successfully answered the question which stumped the "Quiz Kids" at the last meeting. That is, he explained how to put the bubble in a low-pressure manometer.

Robert H. Cooke of Westinghouse entertained and helped educate our members with the Westinghouse movies, "Electronics Today" and "The Ramparts We Build." We recommend both pictures for entertainment and education. —W. A. REICHOW

NEWARK

The Society for Measurement and Control (N. J.) opened its 1944-45 season on Oct. 2 with more than 75 present to hear Mr. James Spencer of Westinghouse speak on "Maintenance and Service on Electrical Instruments." In his talk Mr. Spencer emphasized safety and advised that only safety-minded persons should be permitted to work on electrical instruments. During the question period he could not be budged from his opinion that pivots should be replaced, not sharpened. He pointed out that hardened steel pivots require heat treatment after sharpening, that very few mechanics have the skill to sharpen pivots, and that replacement pivots are inexpensive.

The Instrument Societies Calendar in September listed Mr. Bernhardt as the speaker for our October meeting. As explained in our recent announcement to members, a business trip made it impossible for him to speak at that time and Mr. Spencer kindly agreed to exchange dates with him. Mr. Bernhardt will speak at our December meeting and show the movie "Electronics at Work." —BOB GRAY

NEW YORK

The first fall meeting was held at our new location, the Men's Faculty Club, Columbia University, 400 W. 117th Street, New York City. Mr. Kermit Fisher, president of the Fisher & Porter Co., talked on the "Variable Orifice Flow Meter." The lecture started with a description of the fundamentals for the benefit of anyone not familiar with the instrument. Then follow the development of the meter from earliest history with patent descriptions the latest models. This proved to be most interesting talk as Mr. Fisher a swered many questions during the discu sion period. —R. R. KALBFLEISCH

PHILADELPHIA

The speaker at the September 20 me ing of the Philadelphia Society for I strumentation was Mr. J. A. Pellettere, ch instrument engineer of the Gulf Oil Cor who spoke to us on "Inter-connected I struments," covering ratio instrumentati including combustion control. He present numerous slides showing all types of I struments as applied to specific applic tions. From the application standpoint, considered that the instruments supplied the various instrument manufacturers we very similar. The use of inter-connect instruments had not been developed to t utmost, particularly where process a valve factors entered into the problem.

The classifications into which he group the instruments were as follows:

1. Simple ratio instruments.
2. Combat poor system or valve charac teristics.
3. Provide selectivity or over-ride.
4. To provide invisible limits, i. e., limit actually built into the control instru ment.
5. Provide safety features—

(a) Limits
(b) Over-ride
(c) Sequence timer (ratio and program)

6. Compensate important variables.
7. Program Timers.

The meeting was attended by an en thusiastic group of thirty-five members dinner, with eighty-seven present at the ad dress which followed. —J. E. GAMBRILL

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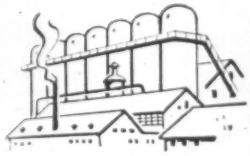

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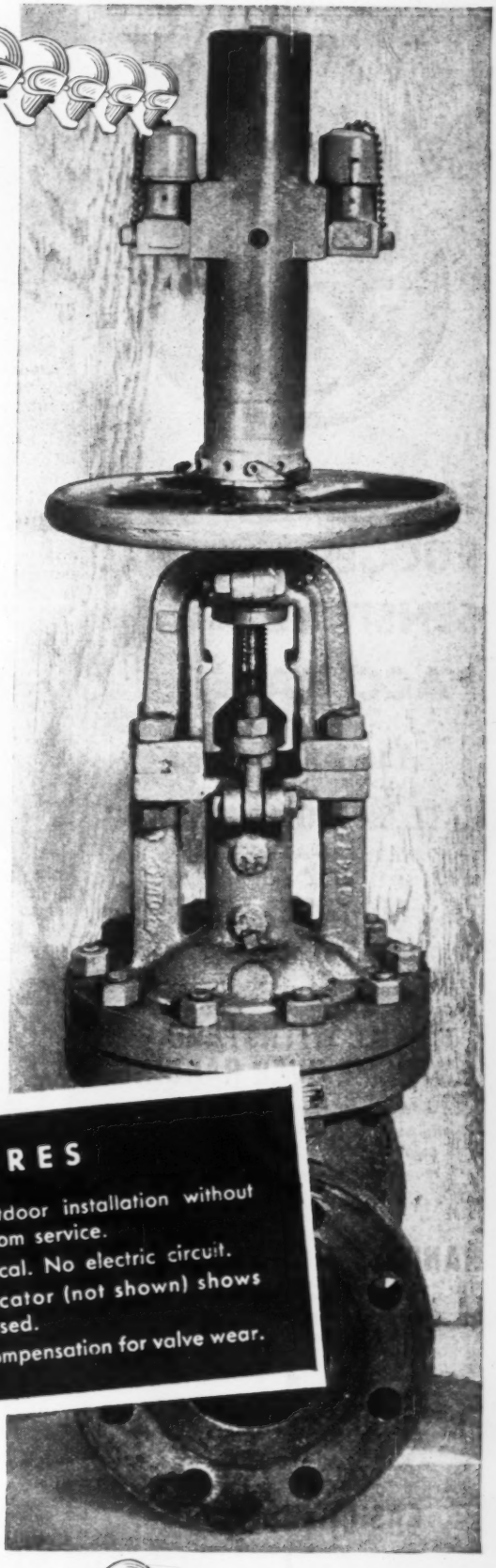

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L-180 **Combustion Control for Boiler Furnaces.** Catalog N-O1P-163, 8½" × 11", 16 pages. Combustion control equipment for small plants where full metered control is not justified. Principles of operation of complete system as well as component parts are explained; specific applications are illustrated. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.

L-181 **Spencer Binocular Microscope for Finish Control.** Folder, 8½" × 11", 4 pages. Binocular microscopes, for visual inspection of surface finishes, which provide magnifications of 108.0X or less. Where it is necessary to make visual inspections of internal surfaces such as pistol or rifle barrels, etc., a small bore inspection telescope is used. Both of these instruments are described and illustrated. George Scherr Co., Inc., 200 Lafayette St., New York 12, N. Y.

L-182 **"Aerovox Research Worker."** May issue, 8½" × 11", 4 pages. This issue explains various methods for using standard frequency transmissions from WWV as an accurate source for calibration of local frequency sources in laboratories and ships. Previous issues of this publication contained the following subjects: "Calibration Sources for Service Test Equipment," Vol. 16, No. 4; "Capacitor Impedance and Resistance Measurements," Parts I and II, Vol. 15, No. 12 and Vol. 16, No. 1, respectively; "Paper Capacitors As Mica Capacitor Substitutes," Vol. 15, No. 11; "An Audio Amplifier Testing Unit," Vol. 15, Nos. 9 and 10; "H. F. Frequency Measurements," Vol. 15, Nos. 4-8, inclusive. Aerovox Corp., New Bedford, Mass.

L-183 **Fluid Metering Pump Systems.** Bulletin, 8½" × 11", 4 pages. Design check chart No. 7 provides performance data and specifications for aircraft pump systems which deliver a metered flow of anti-icer fluid to selected areas of a plane to prevent dangerous ice formations on critical operating parts. These systems are also used to supply accurate quantities of fuel to aircraft unit heaters. Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.

L-184 **"Isodraulic" Control.** Booklet, 8½" × 11", 16 pages. Hydraulic remote control systems with receiver lever movement, and receiver synchronization with the transmitter, controlled by a connecting fluid system. Principles of operation, operating characteristics, dimensions, etc., are explained in text which is illustrated by drawings and charts. Adel Precision Products Corp., Burbank, Calif.

L-185 **Panel Electrical Indicating Instruments.** Bulletin, 8½" × 11", 1 page. Specifications for 2½" class d-c. panel instruments, available in ranges from 100 microamperes to 50 amperes, and from 50 millivolts to 400 volts self-contained. Radio-frequency and rectifier instruments also available. Meters Inc., 915-917 Riveria Drive, Indianapolis, Ind.

L-186 **"Hyprez Finish."** Leaflet, 8½" × 11", one page, describes a new method of assuring a high-precision finish on surfaces prepared by machining, grinding, honing or lapping. No scratch pattern is visible under microscope. Process is recommended for pivots and other instrument parts. Engis Equipment Co., 31 S. Michigan Ave., Chicago 4, Ill.

L-187 **Metering Pump.** Bulletin, 8½" × 11", 8 pages, describes new fluid metering pump (AN 6100-1) in detail with exploded views, performance curves and schematics of recommended installations on aircraft and industrial-plant applications. Adel Precision Products Corp., Burbank, Calif.

L-188 **pH Test Kits.** Bulletin No. 40 B-1, 8½" × 11", 1 page. Describes a small, portable test kit having indicator solution, test tubes, and color chart all housed in a suitable carrying case for colorimetric measurement of pH of solution. Price list included. Connell Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.

L-189 **Drawing Instruments.** Bulletin, 8½" × 11", 4 pages. Illustrates three sets of drawing instruments and gives not only specifications for the complete sets but for the individual instruments as well. Charles Bruning Co., Inc.,

L-190 **Capacitors.** Booklet, 8½" × 11", 40 pages. Written in non-technical language, text describes various types of capacitors and their application in electronic and war equipment. Fifteen pages of color photographs, reproduced by permission of the Signal Corps and of publishers of "Radio News." Solar Mfg. Corp., 285 Madison Ave., N. Y. 17, N. Y.

L-191 **The C-D Capacitor.** March issue, 5½" × 7¾", 16 pages. "Matching Speakers of Unequal Impedance" explains and develops formulae which can be used in connecting two or more speakers of unequal impedance to an amplifier, with each speaker drawing a predetermined amount of the total amplifier output. "Square-wave Testing of Amplifiers" is continued from last issue. "Thermionic Rectifiers Circuits" discusses five different tube circuits, which have proven satisfactory. Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

L-192 **Precision Gages and Inspection Instruments.** Bulletin, 8½" × 11", 16 pages. Colored photographs illustrate plain cylindrical gages, straight-side spline gages, thread ring gages and masters, master gears, gear rolling fixtures, and numerous others. Text explains features of each type illustrated. Vinco Corp., Detroit, Mich.

L-193 **Industrial Thermometers.** Folder, 10½" × 11½", 2 pages. Illustrates indicating and recording temperature instruments for general industrial and marine applications. Also glass stem precision thermometers and hydrometers. Weksler Thermometer Corp., 52-56 West Houston St., New York 12, N. Y.

L-194 **The General Radio Experimenter.** April issue, 6" × 9", 8 pages. Contains two articles: "A Bridge-controlled Oscillator" and "The Effect of Humidity on Electrical Measurements." Latter article discussed the erratic operation of measuring instruments in high relative humidity. General Radio Co., 30 State Street, Cambridge 39, Mass.

L-195 **Ohmite News.** April issue, 8½" × 11", 2 pages. Features a brief biography of Lenze (1804-1865) whose pioneer work developed certain fundamental laws of electricity and magnetism. A second article explains the use of rheostats as transmitting elements in remote control systems. Ohmite Manufacturing Company, 4835-41 Flournoy St., Chicago 24, Ill.

L-196 **Rotameter Sight Flow Meters.** Catalog section 10-B, 8½" × 11", 32 pages. Operating principles, application, and features of fuel flow meters which measure liquid or gas flow rates from ½ c.c. per minute (5 c.c. for air flows) to thousands of gallons or thousands of cubic feet per minute. Text is illustrated by photographs, drawings and charts. Fischer & Porter Co., 923 County Line Road, Hatboro, Penna.

L-197 **Searchray 150.** Folder, 8½" × 11", 4 pages. A complete, self-contained, industrial X-ray unit for the internal inspection of castings, parts, assemblies, etc.; for locating flaws, defects, and improving product quality. Object to be examined is placed in specimen compartment and can first be positioned (before taking the radiograph) by means of the built-in fluoroscopic screen. Specifications are listed. North American Philips Co., Inc., 100 East 42nd Street, New York 17, N. Y.

L-198 **Wheelco Comments.** March-April issue, 8½" × 11", 4 pages. Several articles, one describing the application of temperature control equipment in heat treatment of tools. The second article covers heat treatment of railroad springs. Wheelco Instruments Co., Wheelco Bldg., Harrison and Peoria Sts., Chicago 7, Ill.

L-199 **Thermostatic Expansion Valves.** Bulletin 108, 8½" × 11", 2 pages. Installation adjustment and service instructions for thermostatic expansion valves. Spoehrer-Lange Co., 3723 Commonwealth Ave., St. Louis, Mo.

L-200 **Laboratory and Switchboard Connectors.** Bulletin, 8½" × 11", 12 pages. Specifications for receptacles and plugs of the quick-disconnect type for use in educational and industrial laboratories. Specifications are presented in table form for ready reference, and all connectors listed are illustrated by dimensional drawings or photographs. Cannon Electric Development Co., 3209 Humbolt St., Los Angeles 31, Calif.

L-201 **Photoelectric Densitometers.** Bulletin 316, 8½" × 11", 4 pages. A photoelectric system for the measurement of optical density of liquids, gases, films, and similar transparent materials. Units are designed and built for production testing. Several different types for particular applications are illustrated. Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass.

L-202 **Combustion Regulators.** Bulletin, 8½" × 11", 8 pages. Application of a combustion regulator is explained in text and is illustrated by a large scale drawing of a typical boiler room showing the unit (and its connections) with respect to other boiler room equipment. Other photographs supplement the written information. National Brass Co., Grand Rapids, Mich.

L-203 **Precision Glass Surface Plates.** Folder, 8½" × 11", 4 pages. Pyrex-Brand glass surface plates, flat within 50 millionths of an inch, are available in 12" diameter (2" thick) or a 16" diameter (3" thick). Features and specifications are explained in text. Photographs illustrate uses and their use. Optical flats are also illustrated and priced, as well as gage block sets, etc. George Scheer Co., Inc., 200 Lafayette St., N. Y. 12, N. Y.

NUMBER OF OPERATIONS IN TEST
1,000
2,000
3,000
5,000
10,000
50,000
100,000
200,000
300,000
100%
95%
90%
85%
80%
0
PERCENTAGE OF ACCURACY
COMPLETE FAILURE
MAKE OF WRENCH
"A"- STURTEVANT
"B"- MAKE
"C"- MAKE
"D"- MAKE
Permanently Accurate
STURTEVANT QUALITY
300,000 Deflections
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